ECONOMIC BOTANY

DEVOTED TO APPLIED BOTANY AND PLANT UTILIZATION

The Control of Plant Diseases by Chemotherapy
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Teak in Trinidad — Philip Ross

Investigations on *Simarouba glauca* Dc. in El Salvador — Robert P. Armour

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VOLUME 13

Number 1

January — March, 1959

ECONOMIC BOTANY

Devoted to Applied Botany and Plant Utilization

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Published by
The New York Botanical Garden

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Economic Botany is published quarterly by The New York Botanical Garden, Bronx Park, New York 58, N. Y. Subscription price per annual volume everywhere is $6.00; price per single copy is $1.50. Subscriptions and correspondence should be sent to Economic Botany, The New York Botanical Garden, New York 58, N. Y., and checks should be made payable to Economic Botany. Typescripts should be double-spaced. Photographs will be considered only if of high photographic quality.

Published Quarterly one volume per year, January, April, July and October Kutztown, Pa.

Entered as second-class matter Dec. 15, 1958, at the post office at Kutztown, Pa., under the act of March 3, 1879.

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The Control of Plant Diseases by Chemotherapy

Successful chemotherapy is obtained at present with the antibiotics, such as streptomycin, for certain bacterial and virus diseases of plants. Promising results have been obtained with chemotherapeutic chemicals other than the antibiotics in the control of plant diseases caused by species of such fungi as Botrytis, Fusarium, and Phytophthora.

J. E. LIVINGSTON and M. T. HILBORN[1]

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Introduction

The control of plant disease continues to play an important role in modern agriculture. While much emphasis is placed on the economics of plant disease control, the impact of epiphytotics of certain diseases has had an important place in history. In the years 1845 to 1860 a million people died and one and one half million people migrated from Ireland due to the epiphytotic of potato late blight in 1845 and 1846. During the years 1845-47 famine relief in Ireland cost Great Britain about eight million pounds.

Recently Stakman and Harrar (1957) said that "Unless plant diseases are contained the world's efforts to feed itself cannot be successful. Every loss from disease reduces the average yield per unit of cultivated area, and these losses increase the pressure upon the land available for agricultural production and make even more acute the problem of feeding a growing world population".

Fungicides have been used for the control of plant diseases for almost 3000 years. However, in spite of the synthesis of more effective chemicals and the manufacture of more efficient machinery to apply them the fungi still cause an estimated average annual loss in the United States of three billion dollars. Much of this loss is caused by plant diseases for which no effective control is known. The use of fungicides for the control of plant diseases forms an important part of our economy. According to Fischer (1956) about $82 million is spent for fungicides each year.

Most of the fungicides used in the control of plant diseases are applied to plant surfaces with the intent of preventing fungi from gaining entrance. In other words, these fungicides are "protective" in their action. Other fungicides, and the phenyl mercury materials are one example, may be absorbed to a limited extent and kill fungi inside the plant tissues. In other words such fungicides are "eradicative" in their action. By being absorbed, even though to a very limited extent, the eradicant materials have a type of therapeutic action; and since these fungicides are chemicals, the word "chemotherapeutic"

[1] Plant Pathologists, Pennsylvania Agricultural Experiment Station and Maine Agricultural Experiment Station, respectively.

may be used in describing them. However, the word "chemotherapy" usually has a somewhat different meaning. Webster's dictionary defines chemotherapy in medical terms as "the treatment of internal disease by chemical reagents that have a specific and immediate toxic effect upon the micro-organism that causes the disease, without seriously poisoning the patient". In the case of plants this would imply the absorption of the chemical followed either by its translocation to the site of the organism or an alteration in the physiology of the plant, thereby interfering with the development of the parasite. In either case, it would be a type of systemic activity.

This definition would exclude the protective sprays that are applied to the foliage of plants and that do not penetrate appreciably but would include those fungicides that have an eradicant action. The term "chemotherapy" is used in this paper to indicate the control of plant diseases caused by virus, bacterial and fungal organisms by chemicals that penetrate the host tissues and exert their effect internally. This does not imply that the chemical must be systemic; however, a chemical with systemic activity would be highly desirable.

Chemicals of this type would have several advantages over those presently available, particularly if they possessed systemic activity. Presumably, the plant would not have to be completely covered, such as is now the case with such protective fungicides as the carbamates. Instead, the chemical would exert its effect at some distance from the point of application and could seek out the locus of infection. This would simplify the problem of application permitting a reduction in the volume of spray applied. Another advantage might be that if the chemical persisted in the plant and was still effective for as much as a week or more after application, then the number of sprays that need be applied could be reduced. During early spring when apple trees are developing rapidly it frequently becomes necessary to apply fungicides at three-day intervals in order to protect new growth from infection. A systemic chemical that could be translocated into this new growth and be effective at the locus of infection would be of great value. Still a third advantage might be the use of the airplane for chemotherapeutant application. Herbicides are systemic chemicals, and these have been very effectively applied by airplane. Aerial applications would make it possible to spray cereal crops, forest trees, and certain tropical crops such as rubber and banana trees where conventional equipment is impractical because of the acreage involved, rough terrain, dense undergrowth, lack of water such as occurs in many wheat-producing areas, and too much water such as occurs in many tropical areas.

One of the more recent developments in spray equipment has been the application of fungicides as an air-blast concentrated mist spray. In this type of spraying the amount of fungicide used per unit volume of water is increased, and the spray mixture is injected into a high velocity air stream. One of the major advantages of this method of spraying is that much less water needs to be applied per plant since air is used as the carrier. But this may also have an important disadvantage in that at high concentrations the coverage on the plant surfaces may be poor. A systemic chemical has the potential of overcoming this difficulty. The same may be said for the low gallonage application of fungicides that is coming into such widespread use, particularly on vegetable crops.

Another advantage of a chemical that would act internally would be that a grower could wait until he was certain that control measures were needed. Then he could apply a chemical that would penetrate into the tissues and inactivate the pathogen either by being translocated to the site of infection, or by altering the phy-

siology of the host and rendering it non-susceptible. This type of chemical would appeal to the grower in various ways. The wheat farmer who is growing a low-income-per-acre-crop hesitates to add the cost of a spray to his already high production cost unless he is certain he needs the protection. The apple and potato growers who must annually protect their crop in many areas from scab (*Venturia inaequalis* (Cke.) Wint.) and late blight (*Phytophthora infestans* (Mont.) D. By.) could also reduce their costs by reducing the number of applications. The actual decrease would depend upon the characteristics of the chemical.

An additional advantage would be that the chemical, after it had entered the plant, would be much less affected by environmental conditions than are the protective fungicides. These are frequently washed off by rains, or the chemical may undergo rapid deterioration upon weathering, and frequently when applied under certain weather conditions phytotoxicity results.

The development of efficient chemotherapeutant chemicals would greatly reduce that most time-consuming, labor-wasting, and tedious chore of applying fungicides frequently for the prevention of plant disease.

History

The recent interest in chemotherapy as a means of plant disease control stems from the work of Howard (1941 a, b) and others. Although earlier papers had indicated the promise in this concept of combating plant diseases, most of the rather voluminous literature appeared after Howard's publication. Since most of the literature has been reviewed by Stoddard and Dimond (1949) and by Horsfall and Dimond (1951a, b), little attempt will be made here to present a complete survey. The examples that are cited have been chosen to either illustrate the application of chemotherapy as a new and promising technic in the economic control of plant disease, or to add some of the pertinent literature on the mode of action of chemotherapeutant chemicals.

During the last decade the published literature dealing with chemotherapy has been concentrated to a large extent on the development of antibiotics for the control of bacterial diseases, on the development of chemicals for the control of rusts on cereal crops, and on various wilt diseases. These three general groups of diseases also represent those for which adequate means of control have been largely lacking.

Control Of Bacterial Diseases By Chemotherapy

Vassel (1946) has reviewed the development of drugs for the control of bacterial infections prior to 1946. He points out that beginning in 1905 the research of Ehrlich with arsenicals for the control of syphilis stimulated the investigations with drugs and was the beginning of the concept of chemotherapy. Then when Fleming discovered penicillin in 1929, the era of "wonder drugs" arrived. Following this discovery many drugs were tested for their activity against various organisms. Streptomycin was the first of the drugs, now commonly classed as antibiotics, that showed promise in the control of bacterial plant diseases. One of the most successful uses of streptomycin has been in the control of fire blight (*Erwinia amylovora* (Burrill) Winslow, et.al.) of apple and pear.

Fire Blight of Apple and Pear. In 1952 thiolutin and streptomycin were reported to be possible inhibitors of fire blight on apples (Murneek, 1952). This was followed by the work of Ark (1953) and Heuberger and Poulos (1953). Since these early reports the evidence has been accumulating that streptomycin will control fire blight in concentrations as low as 30 ppm when applied five times during the blossoming period. Young and Winter (1953) found that three applications of

streptomycin at 120 ppm gave 97 per cent control of blossom blight and 100 per cent control of twig blight. Terramycin was also quite effective in the control of this disease. Goodman (1954a) obtained complete control with six applications of streptomycin at a concentration of 100 ppm applied as a spray at four-day intervals beginning at 30 to 50 per cent of full bloom. A high degree of protection was obtained even with a concentration of 25 ppm. Dunegan et al. (1954) found that five applications of a streptomycin + Terramycin mixture at 30 ppm gave the same control as three applications at 100 ppm. Five applications at seven-day intervals of the 30 ppm mixture appeared to have the greatest commercial possibility because it gave good control without the injury to leaves and fruit that occasionally accompanied the higher concentrations. Ark and Alcorn (1956) questioned the advisability of decreasing the concentration below 50 ppm and found that streptomycin alone was just as effective as a streptomycin + Terramycin mixture. They also found that a pyrophyllite + streptomycin dust formulation gave good control of fire blight in a pear orchard when applied every five days during the blooming period. When dealing with *Xanthomonas juglandis* (Pierce) Dowson, a blight of walnuts, they obtained comparable control with a wettable streptomycin formulation at 50 ppm, and a pyrophyllite + streptomycin dust at 500 and 1000 ppm. Under the conditions in Missouri in 1954 good control of fire blight on apples was obtained by Goodman (1954a) with a concentration of streptomycin as low as 25 ppm when applications were started prior to primary infection. When applications were made after primary infection, there was a delay in secondary spread; but satisfactory control was not obtained. Higher concentrations of streptomycin may be needed to control fire blight on pears in Connecticut than on apples in Missouri, according to Miller (1957).

Goodman (1954b) observed slight marginal necrosis on the leaves with 50 ppm but did not find any adverse effect on fruit set, development, or finish with as many as six bloom and post-bloom sprays with concentrations as high as 100 ppm. The results of Miller (1957) in Connecticut would indicate that environmental conditions may influence the degree of control obtained with various concentrations of the chemical. As the conditions become more favorable for blight, the degree of control is less. Winter and Young (1956) agree that environmental conditions have an important role in the degree of control obtained under field conditions. In seasons when the mean temperature during the six days from early bloom through full bloom was 62°F. or 63°F. they obtained good control of fire blight; but when the temperature for the same period of time was only 54°F., the disease control was less.

From the standpoint of the commercial grower five applications of 50 ppm of streptomycin at five to seven day intervals beginning on the balloon stage should give adequate control of fire blight without serious plant injury.

Bacterial Blights of Beans. Zaumeyer, et al., (1953) and Mitchell, et al., (1952, 1954) showed that formulations of streptomycin controlled both halo blight (*Pseudomonas phaesolicola* (Burk.) Dows.) and common blight (*Xanthomonas phaseoli* (E. F. Smith) Dows.). Under greenhouse conditions when a lanolin paste containing 0.2 mg. of dihydro-streptomycin sulfate or streptomycin sulfate was applied to the internode immediately above the cotyledon, it was translocated to leaves six to eight inches from the site of treatment in amounts sufficient to reduce the severity of symptoms. The streptomycin applied to stems could be detected in the leaves, according to Mitchell, et al. (1954). The antibiotic was absorbed and translocated to primary leaves within

eight hours, and the concentration of the free antibiotic was the greatest on the third day. When 100 ppm of streptomycin was applied to the first internode of bean stems, the primary leaves were completely protected from halo blight infection. The streptomycin was translocated from the proximal to the terminal portion of the leaf and from the midrib toward the margin. There was no indication of downward translocation.

Ark and Wilson (1956b) showed that when a streptomycin + pyrophyllite dust formulation was applied to foliage at concentrations of 500 and 1000 ppm the plant juice contained 0 and 7 ppm of streptomycin after one day, and 6 and 5.5 ppm after three days. Gray (1958) working with streptothricin and pleocidin found that these antibiotics were readily translocated both upward to young leaves and downward to older leaves. He obtained control of *Xanthomonas phaseoli* on bean plants when the primary leaves were sprayed with solutions of these two antibiotics.

In field tests Zaumeyer, et al. (1953) obtained a substantial reduction in the incidence of halo blight when plants were sprayed three times with a 0.1 per cent aqueous solution of streptomycin sulfate containing 0.3 per cent Tween 20 as a spreader. Woolliams (1957) found excellent control of halo blight when plants grown from diseased seed were sprayed with streptomycin sulfate. Bean plants grown from field-sown infected seed were sprayed with three weekly applications of streptomycin sulfate at 500 ppm. The first spray was applied when the first pair of trifoliate leaves had developed and after halo blight symptoms had appeared on the foliage. Diseased plants were rogued from all plots just before the second spray was applied. When the seed crop was harvested in the fall, at least 25 per cent of the unsprayed control plants were infected; but no disease appeared in any of the sprayed plots.

On the other hand Marlatt (1955) failed to obtain any control of common blight with four applications of streptomycin and Agrimycin at concentrations as high as 1000 ppm.

The use of glycerol as a spray adjuvant in bacterial blight control has given inconsistent results. Gray (1955a) added one per cent glycerin to a spray containing 50 ppm of streptomycin sulfate and obtained as good control of common blight as with a spray containing 200 ppm without glycerin. Later Gray (1956) reported that the addition of one per cent glycerol to a spray containing 500 ppm of streptomycin increased the absorption five-fold and in 96 hours the increase in absorption was nearly 24-fold. Silber and Kainski (1956) compared a spray of streptomycin sulfate containing 300 ppm with one containing 200 ppm + 0.5 per cent glycerol. They applied the sprays weekly when the trifoliate leaves were expanding. When the inoculum level was high, they found that the spray containing 0.5 per cent glycerol did not give as good disease control as the higher concentration of streptomycin. Ark and Wilson (1956a) did not obtain any improvement in penetration of streptomycin into the leaves with the addition of glycerol. Anderson (1957) increased the activity of sprays containing 200 ppm of streptomycin sulfate with the addition of one per cent glycerol, but he reported no effect on sprays containing 400 ppm.

Smith (1949) soaked seeds for 15 minutes in a 1-100 concentration of streptomycin and completely eliminated bacterial blight under greenhouse conditions. Woolliams (1957) soaked seeds in a streptomycin sulfate solution at concentrations ranging from 50 to 500 ppm and reduced the incidence of halo blight by about half, particularly at the higher concentrations of the antibiotic. Starr, et al. (1951) found that seeds must be soaked from 30 minutes to one hour at a concentration of 1-100 in order to obtain control and that this period of soaking permitted a slipping

of the testas and reduced germination. This slipping of the testas could be prevented, however, by a previous immersion in liquid latex for 30 minutes.

Tobacco Wildfire. Heggested and Clayton (1954) obtained excellent control of wildfire (*Pseudomonas tabaci* (Wolf and Foster) Stevens) of tobacco in plant beds with sprays containing 200 ppm of streptomycin sulfate. The treatment not only prevented infection but also eradicated infection from beds showing considerable disease. These results were essentially duplicated by Beach and Engle (1955).

Kirby (1955) controlled both wildfire and blue mold (*Peronospora tabacina* Adams) with a combination of Agrimycin (streptomycin sulfate 15% + Terramycin 1.5%) and ferbam. Four weekly applications of Agrimycin at 100 ppm plus ferbam at 3 pounds per 100 gallons of water were made beginning when the leaves were the size of a dime.

Shaw and Thorne (1956), Shaw and Lucas (1957), and Shaw, et al. (1957) found that both streptomycin sulfate and streptomycin nitrate gave good control of wildfire when applied as sprays but were not effective when applied as a soil drench or as a dust.

Seed-Piece Decay of Potatoes. Bonde (1953a) tested various formulations of Aureomycin, penicillin, streptomycin, bacitracin, rimocidin, thiolutin, and Terramycin for the control of soft rots of potato tubers caused by *Erwinia atroseptica* (Van Hall) Jennison, and *Pseudomonas fluorescens* Migula. Both dihydrostreptomycin sulfate and streptomycin sulfate were very effective in protecting freshly-cut potato slices from soft rot caused by *E. atroseptica*. Terramycin was only moderately effective in preventing infection. The action of Aureomycin was just the opposite of that for streptomycin. Bonde and Malcolmson (1956) found that at least 9000 pounds of cut seed could be treated in 100 gallons of a streptomycin solution without a reduction in the activity. However, there was an increase in the amount of rot on the cut surfaces caused by species of *Fusarium* and *Phoma*. Later, Malcolmson and Bonde (1956) showed that these fungi could be controlled with a treatment of streptomycin sulfate + rimocidin sulfate, or with 100 ppm of rimocidin sulfate alone. Treating the seed tubers before cutting with nabam, dichlone, and captan also controlled the seed-piece rots caused by fungi. Waggoner (1956) obtained control of *Fusarium sambucinum* Fckl. on cut surfaces of potato slices with captan, dichlone, and rimocidin. Streptomycin solutions not only reduced the percentage of seed-piece decay but also increased stands, reduced the number of plants showing blackleg, generally improved the color, size and vigor of the plants, and increased the yield rate (Bonde, 1955). When streptomycin sulfate was used in combination with Terramycin hydrochloride, the infection of both *E. atroseptica* and *P. fluorescens* was effectively prevented in the greenhouse and in field trials (Bonde, 1955).

Fink (1955) reported an increase in the yield rate from treating potato seed-pieces with streptomycin, streptomycin + Spergon, and streptomycin plus either dichlone, captan, or ferbam in the absence of *E. atroseptica*. Epps (1957) obtained good control of potato seed-piece decay caused by *E. atroseptica* and *E. carotovora* (L. R. Jones) Holland in the field under irrigation by treating the cut seed with either streptomycin dips or dusts. Palm and Young (1957) found that pre-planting treatments of cut-potato seed-pieces would prevent infection of the seed-pieces with either *Bacillus subtilis* (Cohn emend. Prazmowski) or *Fusarium roseum* (LK) emend. Snyder & Hansen (*F. avenaceum*). Either dichlone or captan when combined with streptomycin sulfate, streptomycin nitrate, or Terramycin was effective even after aging for a period of one week.

TABLE 1. SOME EXAMPLES OF DISEASES AT LEAST PARTIALLY CONTROLLED BY ANTIBIOTICS

Crop	Organism	Reference
Apple	*Venturia inaequalis* (Cke.) Wint.	Leben and Keitt (1947) Darpoux and Fairve-Amoit (1951)
Bean	*Erisiphe polygoni* DC	Felber and Hamner (1948) Vaughn, et.al. (1949)
	Colletotrichum lindemunthianum (Sass. & Magn.) Briosi & Cav.	Zaumeyer (1957)
	Uromyces phaseoli (Pers.) Wint. var. *typica* Arth.	Alcorn and Ark (1954) Zaumeyer (1957)
Celery	*Pseudomonas apii* Jagger	Cox (1955)
Cherry	*Coccomyces hiemalis* Higg.	Hamilton and Skolnik (1953) Cation (1953)
Chrysanthemum	*Erwinia chrysanthemi*	Robison, et.al. (1954)
Cole slaw	*Erwinia atroseptica* (van Hall) Jennison	Smith and Hardenburg (1954)
	Erwinia carotovora (Jones) Holland	Smith and Hardenburg (1954)
Corn	*Bacterium stewartii* E. F. Smith	Rich (1956b) Williams and Lockwood (1957)
Cotton	*Xanthomonas malvacearum* (Smith) Dows.	Krasil'nilov (1953)
Crown gall	*Agrobacterium tumefaciens* (Smith & Townsend) Conn.	There has been much work done on the control of crown gall on a variety of plants and an extensive literature has appeared beginning with the work of Brown and Boyle (1944). Much of this literature is reviewed by Klemmer, et.al. (1955)
Crucifers	*Xanthomonas campestris* (Pam.) Dows.	Sutton and Bell (1954)
Cucumber	*Pseudomonas lachrymans* (Smith & Bryan) Carsner	Ark and Wilson (1956)
Cucurbits	*Pseudoperonospora cubensis* (Berk. & Curt.) Rostow	Ark and Thompson (1956)
Elm	*Ceratocystis ulmi* (Buism.) C. Moreau	Szkolnik (1948)
Grape	*Uncinula necator* (Schw.) Burr.	Ogawa and Vergara (1955)
Hops	*Pseudoperonspora humuli* (Miy. & Tak.) G. W. Wils.	Horner and Maier (1957)
Oak	*Ceratocystis fagacearum* (Bretz) Hunt	Phelps, et.al. (1957)
Peach	*Xanthomonas pruni* E. F. Smith	Daines (1956). Daines and Gray (1957)
	Sclerotinia fructicola (Wint.) Rehm.	Ogawa and Davis (1955)
Pepper	*Xanthomonas vesicatoria* (Doidge) Dows.	Altman and Davis (1955) Krupka and Crossan (1955). Cox (1957)
Potato	*Phythophthora infestans* (Mont.) D. By.	Bonde (1953b) Muller, et.al. (1954)
Sesame	*Pseudomonas sesami* Malkoff	Thomas (1956)
Spinach	*Erwinia atroseptica* (van Hall) Jennison	Smith (1955)
	Erwinia carotovora (Jones) Holland	Smith (1955)
Stone fruits	*Pseudomonas syringae* van Hall	Dye and Dye (1954). McKeen (1955)
Tobacco	*Peronospora tabacina* Adam	Anderson (1956)
	Pythium aphanidermatum (Edson) Fritz.	Anderson (1956)

TABLE 1. *Continued*

Tomato	*Alternaria solani* (Ell. & G. Martin) Sor.	Leben and Keitt (1949, 1952)
	Bacillus polymyxa (Prazmowski) Migula	Celino and Gottlieb (1952)
	Botrytis cinerea Pers. ex. Fr.	Brian, et.al. (1951)
	Phytophthora infestans (Mont.) D. By.	Zaumeyer and Doolittle (1956)
	Xanthomonas vesicatoria (Doidge) Dows.	Altman and Davis (1955) Krupka and Crossan (1955). Cox (1957)
Turf	*Sclerotinia homecarpa* F. T. Bennett	Vaughn (1951) Vaughn and Klomparens (1952)
	Helminthosporium sp.	Vaughn (1951) Vaughn and Klomparens (1952)

Antibiotics have shown promise in the control of potato ring rot (*Corynebacterium sepedonicum* (Spiekermann & Kotthoff) Skaptason & Burkholder). Van Schaak (1948) found that penicillin and streptomycin would kill the ring rot organism *in vitro*. When seed was treated prior to planting, the penicillin-treated tubers did not grow; but those treated with streptomycin produced good plants. Logsdon (1957) inoculated tubers with the ring rot organism and then treated them with 1000 ppm of Agrimycin (15% streptomycin + 1.5% oxytetracycline). Only 8 per cent of the hills had symptoms of the disease at harvest time while the untreated controls had 39 per cent. Agritracin (active ingredient-bacitracin) had no significant effect. Treatment of potatoes with higher concentrations of Agrimycin reduced yields per acre. When tubers were treated with a concentration of 5000 ppm, the yield was 3.2 tons per acre in comparison with a yield of 7.5 tons per acre for the untreated controls. The yield decrease was due to a decreased stand, a smaller number of U. S. No. 1 A tubers, and a smaller size of the tubers of this grade.

The diseases that have been discussed so far illustrate some of the more promising uses of antibiotics for the prevention and control of bacterial diseases of plants. The various formulations of streptomycin have thus far found the widest application. However, there are many different antibiotics being tested for their activity against pathogens on a wide variety of plants, as indicated in table 1.

Control of Fungus Diseases by Chemotherapy.

Many different chemicals have been screened to determine their chemotherapeutic activity against fungi. Since any chemical that is to be considered for development will have to compete with the fungicides presently available, it was logical that a considerable portion of the early screening was done against fungi-causing diseases of economic crops that are not now satisfactorily controlled by available fungicides. The rusts and the wilts are two such diseases.

Rusts. The control of the various rust diseases of small grains with fungicides has never been considered practical even though dusting with sulfur has been effective. Greaney (1934a, 1934b) demonstrated that rust on wheat could be controlled by sulfur dust applied at the rate of 30 pounds per acre or even less if the infection was at a low level. When the concept of chemotherapy was revived, encouraging results were obtained in the control of stem rust of wheat by Dickson, et al. (1952). Wheat is a crop that provides relatively low returns per acre to the grower; so any chemical that is satisfactory in disease control not only must

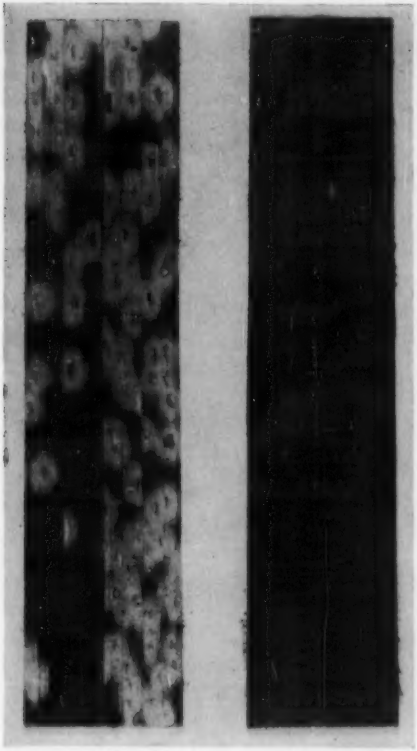

Fig. 1. Leaf rust (*Puccinia rubigo-vera tritici* (Eriks) Carleton) showing control by 15 pounds of calcium sulfamate per acre on the right as compared with an untreated inoculated control on the left.

have a low initial cost but also must be one that can be applied cheaply. Since the airplane has been used so successfully for the application of herbicides, it provides a means whereby chemicals can be applied to large acreages of grain rapidly, relatively inexpensively, and without mechanical injury to the crop.

Livingston (1953) found that calcium sulfamate nearly met the requirements for a satisfactory chemotherapeutant for the control of wheat stem rust (*Puccinia graminis* Pers.) in that it stopped the development of rust pustules following aerial application of 15 pounds per acre in as little as five gallons of water (Fig 1). Unfortunately, undesirable physiological changes were induced in the wheat plants as evidenced by reduced germination of grain from treated fields (Acosta and Livingston, 1955). Mattern and Livingston (1955) showed that calcium sulfamate caused deleterious changes in the wheat kernel when evaluated by the baking test (Fig. 2). Brentzel (1954), Levine (1953) and Semeniuk (1953) also reported that the application of calcium sulfamate reduced both germination and yields. Acosta and Livingston (1955) found that the stage of growth at which the calcium sulfamate was applied had a definite influence on the degree of injury. It should be mentioned that in testing chemicals for their systemic activity they are frequently compared with commonly used preventive fungicides. They have, therefore, often been applied in the same manner as the protectant fungicides, that is, several applications at regular interavls. It is questionable whether this is a desirable practice since a chemical having a systemic action must inactivate a parasitic organism without causing injury to the cells of the host through which the chemical is exerting its influence. It seems logical that there will be a relatively narrow margin of safety requiring a more careful control of the total amount of chemical applied and subsequently absorbed by the plant than is usually necessary in the application of protective fungicides. An exception to this might be a selective chemical having systemic activity. We do know that herbicides of this type are presently available.

Hassebrauk (1952) inhibited spore formation of *Puccinia graminis* and *P. glumarum* (Schm.) Eriks. & Henn. with certain sulphonamides and sulphones. Hotson (1953) also found that certain sulphonamides would suppress the development of *P. graminis tritici* Eriks. & Henn. when applied as a post-infection spray to the plant.

Acti-dione (cycloheximide) has been shown to be effective in reducing the number of pustules and in delaying sporulation of *P. graminis* on wheat (Brentzel, 1955; Livingston, 1953; Silverman and Hart, 1954; and Wallen, 1955). None of these investigators found any reduction in the germination of the grain from treated plants. Mattern and Livingston (1955) have also shown that cycloheximide did not have a detrimental effect on the baking properties of the flour prepared from such grain. However, most of these investigators have found that cycloheximide frequently induces a necrosis of the treated tissues. If the range between fungicidal effectiveness and phytotoxicity can be broadened through further research in formulation, this chemical may find increased commercial application. Hacker and Vaughn (1957a, b) indicate progress in this direction with the semicarbazone of cycloheximide which gave pre-infection resistance to black stem rust in the Onas variety of spring wheat. When treated in the boot stage the plants remained resistant until maturity with no adverse effect on yield or germination. The acetate of cycloheximide also gave good control but did not impart complete resistance.

Many chemicals have been and still are being tested for their activity against the stem rust organism. The authors have tested over 700 chemicals for their activity as chemotherapeutants against stem rust of cereals, rust of beans (Fig. 3), scab of apples, and late blight of potatoes. None has as yet given satisfactory control of disease without at the same time causing some injury to the host.

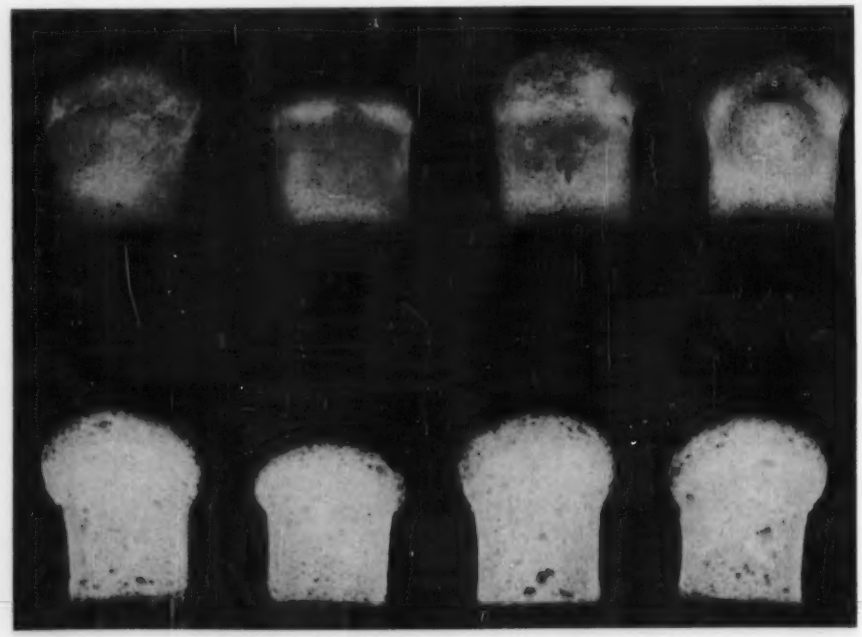

Fig. 2. Loaves of bread baked from flour prepared from wheat treated with systemic fungicides: A, no treatment; B, treated with calcium sulfamate; C, treated with Acti-dione; D, treated with sodium sulfanilate. Courtesy Mattern and Livingston.

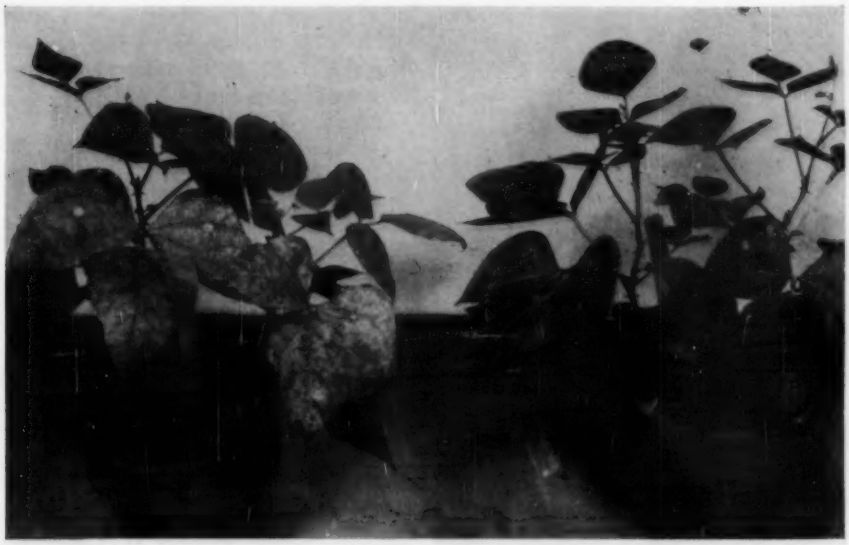

Fig. 3. Control of bean rust (*Uromyces phaseoli typica* Arth.) by chemical 255 on right as compared with untreated bean plant on the left.

Systemic Diseases Caused by Fungi. Caroselli and Howard (1942) injected diaminoazobenzene dihydrochloride into hardwoods infected with bleeding canker (*Phytophthora cactorum* (Lebert & Cohn) Schr.) and greatly reduced symptoms of the disease by counteracting the toxin produced by the fungus. Zentmyer and Horsfall (1943) found that another wilt-producing disease, Dutch elm (*Ceratocystis ulmi* (Buisman) C. Moreau) (Fig. 4) could be combated by injecting elm trees with 8-quinolinol benzoate and 8-quinolinol sulfate. Dimond (1947) and Dimond, et al. (1949) showed that these chemicals were much more effective if they were present in the tree when infection occurred. A more uniform distribution in the tree was obtained when the chemical was applied to the soil and absorbed through the roots. This treatment does not give the desired degree of control, but it does prolong the life of the elm trees by several years.

Later, Caroselli, et al. (1951) in studying the Dutch elm disease, reported that soil injection of low magnesium lime, salicylate, and urea caused a 70 per cent reduction in symptom expression and that this reduction lasted for more than two years. More recently other chemicals have shown some effect in the control of Dutch elm disease. Dimond and Davis (1952) found that when 2-carboxymethylmercaptobenzothiazole salts were applied as a foliage spray the symptoms of the disease were reduced. Tarjan and Howard (1953) obtained a material reduction in symptoms when nursery trees were injected with benzothiazole 1-2 thioglycollic acid, salicylic acid, Helione A, and 8-hydroxyquinone benzoate if these chemicals were applied prior to inoculation with the fungus.

Some recent work by Beckman and Howard (1957) suggests that the inhibition of the Dutch elm disease may be due to the effect that some chemicals have on limiting the development of wood suscep-

Fig. 4. Elm trees injured by the Dutch elm disease.

tible to infection. They injected sodium 4,5-dimethyl thiazolylmercaptoacetate into elm trees during bud swelling and bud break and reduced springwood formation by as much as 80 per cent. Single applications and also three weekly applications reduced infections by the fungus to a marked extent, but when springwood formation was better developed, as was the case later in June, the chemical failed to reduce infection.

Hoffman (1951) inhibited the germination of the spores causing oak wilt (*Ceratocystis fagaccarum* (Bretz.) Hunt) with 16 different compounds and inactivated the toxin produced by the fungus with phenyl mercury lactate and diphenyl quanidine phthalate. Later (1952, 1953) he found that such chemicals as urea, lime, oxyquinoline sulfate, oxyquinoline benzoate, and undecylenic acid showed some effect in field tests. Hoffman points out that the chemicals that showed an effect in combating oak wilt were mostly basic in nature which suggests that they may be neutralizing the toxin since in the neutral and alkaline range the toxin becomes inactive. Schneider (1957) exposed both *C. ulmi* and *C. fagacearum* to a number of different inhibitory chemicals in agar and found that when these fungi were transferred to the same medium free of the chemical they resumed growth within a week indicating that the action of the chemical was fungistatic rather than fungicidal.

Wilts caused by various species of *Fusarium* have been studied intensively. Numerous compounds have been tested and several show considerable activity. Dimond, et al. (1951), Stoddard (1951a), and Stoddard, et al. (1951) obtained excellent control of *Fusarium dianthi* P & D on carnations with 2-norcamphane methanol and 4-chloro-3,5-dimethylphenoxyethanol at rather low dilutions. The latter compound also showed promise in the control of *Fusarium* wilt of tomato. Davis and Dimond (1952) found that 4-chloro-3,5-dimethylphenoxyethanol would reduce the disease on tomatoes, yet the chemical itself was not present in the plant in fungitoxic concentrations. This suggests that the increased resistance to *Fusarium* wilt was due to an alteration in the host metabolism.

Plant growth regulators have also shown promise in the control of *Fusarium* wilt of tomatoes. Davis (1952b) and Davis and Dimond (1953, 1956) showed that 2,4-Dichlorophenoxyacetic acid, γ-naphthalene acetic acid, 2,3,5-triiodobenzoic acid, β-naphthoxyacetic acid, and 3-indoleacetic acid all increased resistance to disease. The effect of treatment was always more pronounced with time, yet the chemicals were absorbed within the first few hours. Because of this these investigators postulated that the growth regulators reduce disease by inducing changes in the host

metabolism which regulates the growth of the parasite and/or the elaboration of toxins. Corden and Dimond (1957) investigated a series of naphthalene-substituted aliphatic acids having chain lengths of two or four carbon atoms and found that the ability of these compounds to inhibit root elongation was related to their ability to induce disease resistance.

That the formative effects of various compounds is related to the ability of a compound to induce disease resistance has been well illustrated by the work of Davis, et al. (1954a, 1954b), and Dimond and Davis (1953). Much of this research was concerned with benzothiazole and related compounds when tested against *Fusarium oxysporum f. lycopersici* (Sacc.) Snyder & Hansen in tomatoes. It was shown that the compounds did not accumulate sufficiently in the plant to account for their chemotherapeutic activity, but that there was a marked increase in the levels of water-soluble nitrogen fractions.

Although the auxin-like growth regulators seem to increase disease resistance as their concentration and the time between their application and disease inoculation increases, not all growth-influencing compounds act alike. Dimond and Corden (1957) have pointed out that gibberellic acid continues to affect resistance of tomato to *Fusarium* wilt even after its growth-influencing effect has disappeared.

Other chemicals, such as some of the phenols and quinones, have been shown to have some effect on the control of *Fusarium* wilt of various plants by Toole (1950) and LeTourneau, et al. (1956, 1957).

Gopalkrishman and Jump (1952) inhibited the growth of *Fusarium oxysporum f. lycopersici* in culture with thiolutin, but in sand or soil the antibiotic was less effective. Antibiosis has shown promise in the control of *Fusarium* wilts in the work of other investigators. Ark, et al. (1951) found that some strains of *Streptomyces scabies* showed antibiotic activity against *F. oxysporum*. Bega (1954) observed that with simultaneous inoculation with sweet potato sprout rot (*F. solani f. batatas* McClure) and *F. oxysporum f. batata* (Wr.) Sndy. & Hans.) the sweet potato rot fungus inhibited the wilt-producing *Fusarium*. Smith (1957) found that *Fusarium oxysporum f. lycopersici* was inhibited in culture by a fungus, *Micromonospora sp.*, which could be isolated from a small percentage of apparently healthy tomato plants.

Waggoner and Dimond (1952, 1956a, 1956b, and 1957) investigated the possibility of altering disease resistance with ionizing radiation. They found that irradiating the roots of tomatoes with x-rays before inoculation with *F. oxysporum f. lycopersici* increased the resistance of the plants to infection. This resistance lasted for two to four weeks and seemed to be due to an alteration in the auxin level of the plant.

Other Fungus Diseases. Following the work of Crowdy (1951), Crowdy, et al. (1951, 1952) with *Botrytis cinerea* Pers. ex. Fr. and *B. fabae* Sardina on tomato and broad bean, and the report of Stoddard (1951b, 1951c) on the control of red stele (*Phytophthora fragariae* Desm. & Rob.) on strawberry and extensive literature began to appear on the control by chemotherapy of many diseases of plants. Some pertinent ones selected to illustrate the wide range of fungi and host plants are listed below.

Alternaria solani (Ell. & G. Martin) Sor. — on tomato. McNew and Sundholm (1949)

Cladosporium cucumerinum Ell. and Arth. — on cucumber. Stoddard (1954)

Fusarium oxysporum Schlecht. *f. gladoli* (Massey) Sny. & Han. — on gladiolus. Scurti (1952)

Phytophthora cinnamomi Rands — on avocado. Zentmyer (1954). Zentmyer and Erspamer (1957)

Phytophthora parasitica Dast. — on tomato. Newton (1957)

Phytophthora parasitica Dast var. *nicotianae* (Bread de Hann) Tucker — on tobacco. Newton (1957)

Rhizoctonia solani Kuehn — on turf grass. Shurtleff (1955). On greenhouse stock. Stoddard (1952)
Uromyces phaseoli (Pers.) Wint. — on bean. Sempio (1936)
Venturia inaequalis (Cke.) Wint. — on apple. Howard and Sorrell (1943). Kuc, Williams and Shay (1957)

It is not difficult to find chemicals that are toxic to the organism, but it is difficult to obtain a chemical that will exhibit systemic activity and be toxic to the parasite while being non-toxic to the host. In some instances where disease losses are high and where the cash return from the crop would also be high in the absence of plant disease, it may be practical to use certain chemicals even though these may be slightly phytotoxic and cause some reduction in yield.

The principal disadvantage of the systemic chemicals presently available is that they are generally effective within the plant for a comparatively short period of time. This is a distinct disadvantage with those plant diseases that persist in the soil, because in such cases the plants are constantly being subjected to reinfection.

Seed-borne Diseases. Paulus and Starr (1951) tested eight antibiotics for the control of loose smut, *Ustilago nuda* (Jens.) Rostr., and found that streptomycin sulfate gave the best results by reducing infection to one-half that of the check. Porter (1956) did not obtain control with Aureomycin, magnamycin, or Terramycin. Leben, et al. (1953) found that seed treatment with Helixin B not only gave control of barley loose smut but also aided in the control of wheat bunt, *Tilletia foetida* (Wallr.) Liro., oat smut, *Ustilago avenae* (Pers.) Rostr., and covered smut of barley, *Ustilago hordei* (Pers.) Lagerh. Leukel and Mitchell (1956) obtained good control of covered kernel smut of sorghum, *Sphacelotheca sorghi* (Link) Clint., with an unpurified antibiotic mixture obtained from a strain of *Streptomyces*. The mixture was effective when used either as a dust or as a seed soak. Henry, et al. (1952) prevented infection of spring wheat from seedborne spores of bunt, *Tilletia caries* (DC.) Tul. and *T. foetida* with both dust and aerosol preparations of Acti-dione. Later, Henry, et al. (1953) found that although Acti-dione gave good control of bunt the emergence rate of the seed was not improved. A combination of captan and Acti-dione made a satisfactory seed treatment because it gave good disease control and improved the rate of emergence.

Leben, et al. (1952, 1953) found that Helixin B when used as a seed treatment controlled both *Helminthosporium victoriae* M. & M. and *H. sativum* P. K. & B. as well as some of the covered smuts of cereals. Leben, et al. (1954) reported that various antibiotics, Helixin A, B, and C, and antimycin A-35, reduced the infection of *H. victoriae* on Vicland oats.

Control of Virus Diseases by Chemotherapy

The virus diseases represent another group for which a chemotherapeutant would be particularly valuable. Fungicides are generally of no value in either preventing or controlling the virus diseases. Eradicating infected plants and controlling insect vectors will effectively prevent the introduction and spread of many virus diseases, but once a plant is infected there is little that can be done at present of a remedial nature.

Stoddard (1947) was able to inactivate the virus of X disease in peach trees when he budded diseased buds into healthy trees that had previously been treated with calcium chloride, zinc sulfate, and sulfanilamide. Rumley and Thomas (1951) successfully inactivated carnation mosaic virus with calcium chloride and zinc sulfate, but the resulting injury made the treatment impractical. However, Rich (1954, 1956a) obtained good control of

big vein of lettuce with calcium chloride at 1000 ppm and zinc sulfate at 250 ppm.

Some of the growth-regulating substances have also been used in studying the chemotherapy of plant virus diseases. Limmasset, et al. (1948) and Locke (1948) retarded the X and Y viruses and leafroll of potato with 2,4-dichlorophenoxyacetic acid and some of its derivatives. Nichols (1952) was able to retard the development of tobacco mosaic virus with some of the growth-regulating compounds, particularly naphthalene acetic acid and indolebutyric aicd. Rich (1954, 1956a) obtained good control of lettuce big vein with naphthalene acetic acid, 2,4,6-trichlorophenoxyacetic acid, and indoleacetic acid. Recently Maramorosch (1957) found that gibberellic acid would overcome the stunting effect due to corn stunt virus infection, but the diseased plants still showed other symptoms of the virus. Porter, F. M., et al. (1957) screened 529 compounds and found that one substituted carbamate, fufuryl 5-chloro-2-methylcarbanilate suppressed symptoms of southern bean mosaic by 98 to 99 per cent.

The antibiotics have also been used in the chemotherapy of viruses. Leben and Fulton (1952) reported that two antibiotics, streptothricin and Terramycin, suppressed lesion formation by tobacco necrosis and tobacco ringspot viruses. Schlegel and Rawlings (1954) and Gray (1955b) obtained inhibition of tobacco mosaic virus with an antibiotic obtained from *Nocardia formica*. KenKnight (1955) reported that trees infected with peach rosette virus showed some recovery when treated with achromycin, Agrimycin, Aureomycin hydrochloride, and Terramycin. No recovery from virus infection was observed when Acti-dione, endomycin, neomycin, or streptomycin was used.

Davis (1952a) postulated that since 4-chloro-3,5-dimethylphenoxyethanol seemed to induce resistance to *Fusarium* wilt of tomato by altering host metabolism it should also have an effect against tobacco mosaic virus. It was found that the chemical would not inactivate the virus *in vitro* but would increase resistance of plants when 50 ml of a 16 ppm solution was added daily to the test plants. Schlegel, et al. (1953) found that radiophosphorus, P 32, in young tobacco leaves infected with mosaic inhibited virus formation and mosaic symptom expression.

A number of investigators have shown that the rate of multiplication of cucumber mosaic virus and tobacco mosaic virus can be inhibited by treatment with thiouracil (Nichols (1953, 1954), Holmes (1954), Gray (1955b), and Porter and Weinstein (1957a, 1957b, 1957c)). The latter reference contains an excellent review of the literature. Holmes (1954) found that if treatment with thiouracil was delayed until just after primary lesions appeared, then almost all plants receiving 5 ml daily as a soil drench were able to grow to maturity, blossom, and set seed. The control of the disease appeared to be complete. Pollard and Dimond (1956) reported that bombarding tobacco mosaic virus with alpha particles and deuterons would cause inactivation of the virus.

Other chemical treatments have shown an effect against virus diseases. Takahashi (1948, 1957) inhibited tobacco mosaic virus by using malachite green. Woods (1943) inhibited the multiplication of the same virus with cyanide, while Kalmus and Kassanis (1944) reduced the susceptibility of beans to tobacco necrosis viruses with carbon dioxide. McKeen (1956) found that juice expressed from pepper, *Capsicum frutescens L.*, contains a substance that inhibits the production of local lesions of certain viruses on cowpea, *Chenopodium hybridum* L., *Physalis peruviana* L., and certain varieties of tobacco when applied with the virus inoculum or to leaf surfaces before inoculation. If applied after inoculation the virus was not inhibited. Millikan and Guengerich (1957) reported that 8-azoquanine and thiouracil showed

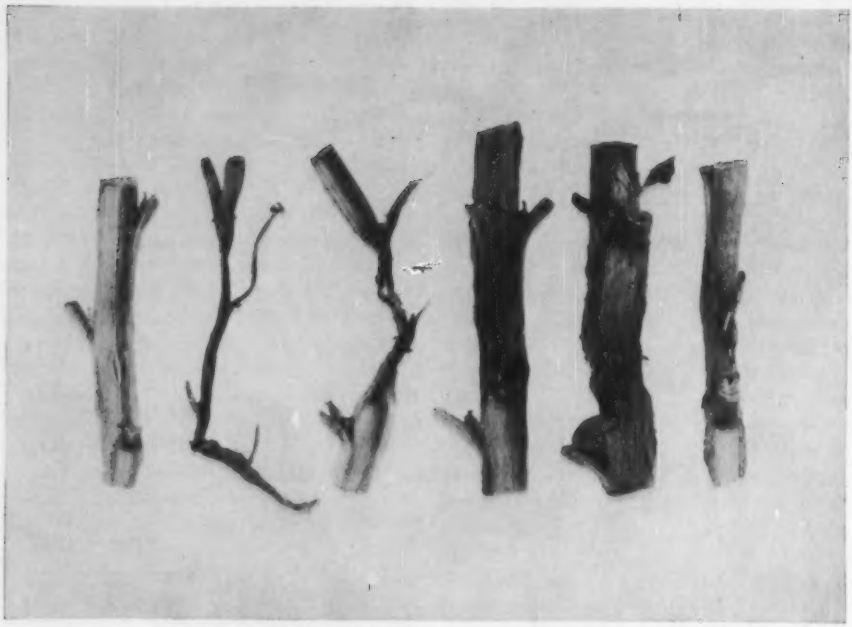

Fig. 5. Effect of some chemotherapeutants on the infection of potato stems by *Rhizoctonia solani*.
left = control, inoculated with sterile water
next = control, inoculated with *Rhizoctonia solani* (notice tissue collapse)
next = partial inhibition of infection by oxyquinoline sulfate 1:1000
next = partial inhibition of infection by indole acetic acid 1:100
next = partial inhibition of infection by 2-norcamphane methanol
right = partial inhibition of infection by 4-chloro-3,5-dimethylphenoxyethanol

inhibition of necrotic ring spot in plum, and Kirkpatrick and Lindner (1954) found that chloramphenicol, thiouracil, and guanazola inhibited a virus disease of stone fruits as well as tobacco mosaic virus on tomatoes.

Mode of Action

In order for a chemical to control a disease of a plant caused by a parasite there must be an effect upon the parasite or upon the host plant. Some of these effects have been discussed by Stoddard and Dimond (1949) and by Horsfall and Dimond (1951a, b). Hilborn (1953) pointed out that there may be a complex reaction in the plant since the same chemical acting on the same pathogen may have different effects in different hosts.

The action of the chemical on the parasite may be (1) eradication, (2) growth inhibition, (3) prevention of sporulation, (4) prevention of toxin formation, and (5) inactivation of a toxin after production. The action on the host plant may be much more complex. For example, certain chemicals have formative effects and may cause an increase in the water-soluble nitrogen fractions, change the level of reducing sugars, or affect enzymatic systems. Other, and even more complex, reactions in the host tissue may also occur.

The primary action of chemotherapeutants on the host is to either increase or decrease susceptibility. An ideal type of action would seem to be one where the chemical could be applied by any of several methods and would then bring about a physiological change within the host, rendering it resistant to the attack of the organism or to the production of a diseased condition. Several types of activity are represented by the chemicals under discussion. This not only is to be expected but is probably desirable since different organisms affect plants in different ways. A single type of action would not likely be effective in preventing all the different types of diseases.

A relatively simple modification of a chemotherapeutant chemical may alter its effectiveness. LeTourneau, et al. (1957) have shown that, although catechol with hydroxyl groups in the ortho position was the most inhibitory of 17 phenols, phenolic acids, and quinones that were studied, the replacement of a hydroxyl group with a carboxyl group decreased the effectiveness. Chlorination of the quinones, on the other hand, increased the effectiveness. Several other workers have pointed out similar effects, among them Davis, et al. (1954a) who showed that some five-membered heterocyclic compounds were not chemotherapeutic with one benzene ring but were with two benzene rings.

Pramer, et al. (1956) studied the mode of action of antibiotics in plant disease control. They postulated that an antibiotic may control disease by (1) acting directly on the pathogen, (2) neutralizing toxins secreted by a pathogen, (3) acting on the host, (4) being transformed within the plant to a substance having greater or different activity, or (5) by a combination of two or more of the possibilities previously listed. It was also pointed out that there are no data regarding the ability of antibiotics to neutralize toxins, and little data as to how antibiotics alter metabolism and thereby confer resistance.

Streptomycin. There is no question that streptomycin is absorbed. Anderson and Nienow (1947) extracted sap containing 4 to 5 ppm of streptomycin from soybean plants growing in a nutrient solution containing the antibiotic. Mitchell, et al. (1952, 1953, 1954) applied streptomycin in a lanolin-Tween 20 paste to the first internode of the stems of bean plants and obtained a measurable amount of free streptomycin from the primary leaves within 8 hours. The maximum concentration of streptomycin in the primary leaves occurred on the third day and by the fifth day following treatment as much as 67 per cent of the total streptomycin applied had been translocated to the primary leaves as free streptomycin. Movement from stems to leaves and from proximal to distal portions of the leaves was demonstrated, but no movement in the reverse direction was detected. The streptomycin did not accumulate in the seeds of treated plants in sufficient amounts to prevent infection of plants grown from these seeds following inoculation by *Phytomonas medicaginis* var. *phaseolicola* (Burk., Stapp, & Kotte).

Mitchell, et al. (1953) failed to obtain absorption of streptomycin from the soil by bean plants. Dye (1956a) on the other hand showed that peach seedlings growing in a nutrient solution containing streptomycin sometimes accumulated the antibiotic in the leaves in greater concentration than it existed in the solution surrounding the roots. However, when the solution was applied to the leaves there was no evidence that the antibiotic was systemic suggesting that it may become bound in the leaf tissues (Dye, 1956b). These results confirm those of Pramer (1953) and Crowdy and Pramer (1955) who found that absorption by the plant and distribution within the plant varied with both the plant species and the antibiotic tested.

Gray (1955a, 1956) demonstrated that the addition of glycerin greatly increased

the absorption of streptomycin by bean leaves, but, as discussed earlier under bacterial blights of beans, there seems to be some disagreement on the efficiency of glycerol as an additive to streptomycin. Goodman and Hemphill (1954) and Hemphill and Goodman (1955) demonstrated that adding either indole-3-acetic acid or ethyl-3-acetate increased the control of fire blight in apple shoots. They postulated that many plant growth regulators would have this effect and suggested that the reason may be due to an increase in water uptake or an increase in the permeability of cell membranes rather than an effect on the pathogen.

In view of the evidence that streptomycin is present in the leaf tissue as free streptomycin, it is logical to conclude that its activity is directly on the organism. Fitzgerald and Bernheim (1948) found that the enzymes produced by *Mycobacterium lacticola* (Lehmann and Neumann) which oxidize benzoic acid are relatively insensitive to streptomycin. They suggest that streptomycin inhibits the formation of these enzymes. This would indicate that the action of streptomycin against bacteria might be one of inhibition rather than eradication. This is not borne out by the work of Baver (1951), however, who found that the cells of *Bacterium lactis aerogenes* Escherich required a long lag period in either liquid or solid media following treatment with streptomycin. This suggests a modification of the cell protoplasm. Heggested and Clayton (1954) conclude on the basis of circumstantial evidence that the action of streptomycin in the control of wildfire of tobacco is both eradicant and protective. Dufrenoy (1949) pointed out that streptomycin does not adversely affect desoxyribonucleic acid derivatives involved in the nuclear structure of plant cells, but it may adversely affect chlorophyll-bearing cells by linking with ribonucleic acid.

Cycloheximide (Acti-dione). The systemic nature of cycloheximide has been demonstrated by several workers, Hamilton, et al. (1953, 1956), Kornfeld, et al. (1949), Hacker and Vaughn (1957a, b), Lemin and Magee (1957), and Ford and Leach (1948).

Ford and Leach (1948) and Lemin and Magee (1957) showed that radioactive cycloheximide acetate is taken up by roots of intact tomato plants and transported into the leaves in quantities sufficient to be antifungal. Their evidence from chromatographic studies indicated that the antifungal activity came from free cycloheximide released in the tissues of the plant. Hamilton and Szkolnik (1953) found no evidence of translocation of cycloheximide from one leaf to another although the antibiotic was readily absorbed by the foliage, and leaves with functional stomates were protected indefinitely from infection by *Coccomyces hiemalis* Hig.

Whiffen (1951) found that when the sporophytes of *Allomyces arbuscola* Butler were treated with cycloheximide cytological changes could be induced. Gameotophytic outgrowths occurred indicating somatic reduction. When sporophytic hyphae were grown from a treated fungus, both haploid and diploid nuclei were present and the hyphae exhibited both sporophytic and gametophytic tendencies. Berliner and Olive (1953) found that cycloheximide almost completely inhibited basidial development in *Gymnosporangium clavipes* Cke. & Pk., and the nuclei became very large with much extended chromosomes. Many basidia were found with two nuclei closely associated or still connected by chromatic strands indicating an interference with spindle formation.

Sulfonamides. Hotson (1953) reported on the activity of sulfonamide derivatives in inhibiting the development of *P. graminis tritici* in wheat. Several of the sulfa drugs controlled stem rust when applied as a spray at rates as low as 5 pounds per acre after infection had occurred. Of

particular interest is the renewal of growth within a period of 3 days of the rust organism in the tissue when the plant is sprayed with 300 ppm of para-amino benzoic acid. Folic acid also caused a renewal of growth.

Henry (1944) has reviewed the action of sulfonamides and indicated that para-amino benzoic acid is an intermediate step in the synthesis of folic acid. The sulfonamides are similar in chemical structure to para-amino benzoic acid, and when they are applied to the infected plant the fungus takes up the sulfa drug but is unable to use it in the synthesis of folic acid. The fungus, however, is not killed and when para-amino benzoic acid is again made available the fungus can recover and resume normal activity.

Against Wilts Caused by Fungi. It is generally recognized that a chemotherapeutant may control a plant disease by either a direct action on the fungus, by counteracting a toxin produced by the fungus, or by inducing a physiological reaction by the host. Of course combinations of one or more of these actions may also occur.

Howard (1941a, b) reported that diaminoazobenzene dihydrochloride when injected into maple trees brought about recovery from bleeding canker caused by *Phytophthora cactorum* (L. & C.) Schroet.

Dimond, et al. (1949) and Zentmeyer, et al. (1943) showed that 8-quinolinol benzoate acted as an antidote to a toxin in the control of Dutch elm disease when applied to the soil and absorbed through the roots.

Extensive investigations of the role of chemotherapeutants in the control of Fusarium wilt of tomatoes (*Fusarium oxysporum f. lycopersici*) by Dimond, et al. (1952), Davis and Dimond (1952), Horsfall and Dimond (1951a, b), and Dimond and Davis (1953) revealed that the most effective chemicals were those that also caused injury to the roots. These chemicals apparently made the plant more resistant by altering the metabolism of the host. The work with 2,4-D and its effect upon disease development suggests that the level of reducing sugars and nitrates may be very important in the susceptibility of plants to disease (Hsia and Christensen, 1951; Ibrahim, 1951; Stahler and Whitehead, 1951; and Wolf, et al., 1950). However, the effect may be due to the altered nutrient balance rather than to the increase or decrease of any specific nutrient.

Crowdy and Wain (1951), in their early work, asumed that the chemicals they were testing were toxic directly to the pathogen in the host. This likewise was the assumption of Gassner and Hassebruck (1936) and Livingston (1953) in their work on the control of rust of wheat. This idea gained some support from the work of Hotson (1953) when he showed that sulfonamide stopped the growth of the rust fungus by interfering with its metabolism.

Horsfall and Rich (1951) showed that some compounds exert their effect mainly by inhibiting sporulation. This would give effective control of those diseases like rusts and late blight of potatoes where development to epiphytotic proportions is dependent upon the production of spores in great numbers.

Conclusion

It is not at all difficult to find chemicals that are active against pathogenic organisms. However, it has proven to be difficult to find a chemical that is active systemically against a plant pathogen without at the same time inducing some undesirable effect on the host plant.

Some of the antibiotics, particularly streptomycin, have apparently found a place in the commercial control of some bacterial diseases of plants. The control of fire blight of fruit trees and the control of potato seed-piece decay are two examples. Some of the antibiotics are truly systemic and may be applied as seed treatments for the control of foliage diseases.

Antibiotics, such as cycloheximide, are proving to be effective in the control of some fungus diseases, particularly wheat rust and cherry leaf spot.

Chemotherapeutic chemicals, other than the antibiotics, seem to be somewhat effective in the control of various wilt diseases such as *Fusarium*, and there are promising results in the control of such plant pathogens as *Botrytis cinerea* and *Phytophthora fragariae*.

Some of these chemotherapeutic chemicals, such as the sulfa compounds, appear to be effective because they literally confuse the pathogen. In its search for food the fungus cannot distinguish a vitamin-supplying chemical that is necessary for fungus growth. Instead it will absorb into its metabolic processes a chemical that is closely related in molecular configuration but which will not supply the necessary growth factor.

Other chemotherapeutants exert their effect on plant pathogens by altering the host metabolism and in this way create an unfavorable environment for the pathogen.

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Utilization Abstract

Arizona Plant Waxes. The author studied 42 species of Arizona plants, selected for the occurrence of wax-like material or a heavy bloom on the stems or leaves and for a thick cuticle. A species may rank very poorly in regard to yield of wax when the yield is expressed on a plant-weight basis, but the species may actually have a relatively large amount of wax per unit of plant surface. For example, the yield of wax from *Asclepias albicans* and from *Simmondsia chinensis* is very low on a plant weight basis, but on the basis of yield of weight of wax per unit surface area these species rank high, yielding almost half as much wax as carnauba palm. Other Arizona plants that yield considerable wax on a surface area basis are *Larrea tridentata, Juniperus deppeana,* and *Prosopis juliflora* var. *velutina.* Most of the xerophytes and succulents studied contain only small amounts of wax. Apparently the thick cuticles of many desert plants, such as *Agave, Opuntia,* and even *Asclepias albicans,* are composed mainly of substances that are not waxes. The often quoted assertion that "plants indigenous to arid and hot regions have waxy cuticles" is untenable and should be altered to read "wax-like cuticles." *(E. B. Kurtz, Jr., Jour. Amer. Oil Chem. Soc. 35 (9): 465-467. 1958.)*

JWT

Teak in Trinidad

Teak plantations have been established in Trinidad to provide first quality timber for the future. Thinnings from the teak plantations are being utilized by the "Brickfield Forest Industries" which produces fences, building and construction lumber, and creosoted posts and poles.

PHILIP ROSS, Ph.D.[1]

Forest trees that produce first quality wood are limited in number and abundance on the island of Trinidad. Years of selective cutting by private individuals have depleted the natural vegetation of the following timber trees: West Indian cedar, *Cedrela mexicana* Roem.; cyp, *Cordia alliodora* (Ruiz & Fav.) Cham.; locust, *Hymenaea courbaril* L.; balata, *Manilkara bidentata* (A. DC.) A. Chev.; and mora, *Mora excelsa* Benth. In 1956, slightly less than 1.3 million cubic feet of non-coniferous logs, coniferous and non-coniferous sawn lumber and poles were imported, against 28,900 cubic feet exported (1). In 1913 C. S. Rogers, Forest Officer, looking for a first quality wood, introduced teak seeds from Burma and planted them in the Southern Watershed Reserve. Small areas were planted each succeeding year until 1920 when the total area of teak plantations was 71 acres. In 1928 a definite teak plantation program was established, and teak was planted on a considerably larger scale. Fresh seeds were brought in from India in 1936 (2). Since then the Forest Department has set up a general plan for teak plantations calling for 800 acres per annum to be planted in teak, and this target was reached in 1956 and 1957. As Trinidad teak falls between Classes I and II of the Indian Nilembur plantation quality class scale, the yield of the final fellings of teak by 1990 will not be less than 1.5 million cubic feet a year (10).

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Taxonomy and Nomenclature

Teak is a member of the Verbenaceae in which about 75 genera and 1,300 species are to be found. There are three species in the small genus *Tectona*, but *Tectona grandis* L. f. is the only true teak. *Tectona tenuifolia* Buch-Ham, is found in Burma, and *T. phillipinensis* Benth. and Hook. f. is indigenous to the northern Philippine Islands (6). The word "teak" is derived probably from the Portugese word "teke" or "teca" which was adapted from the word "teka" of the Dravidian languages meaning "building or construction". In Sanskrit the word for teak is "saka," in India it is "jati," and in Siam "sak." Indian teak wood has been used for over 2,000 years as a building material; the old town of Siraf on the Persian Gulf is almost entirely built of it (8).

Teak is indigenous throughout Burma, the Indian Peninsula, and the islands in the Indian Archipelago, where it occurs normally in the mixed deciduous forest (11). Teak in Trinidad compares very favorably in growth increment with teak in its natural areas. Mature teak trees in native habitats reach a height of 192 feet and a girth of 26 feet or more. The trees in the older plantations on the island of Trinidad have tall, cylindrical, slightly fluted boles which are buttressed at the end. Fluting when it does occur seems to result from a high water table or excessive branching (4). The branchlets are quadrangular in shape, channelled, and have a large quadrangular pith. The opposite leaves are

broadly elliptical or obovate, usually one to two feet in length, but often larger in young plants and coppice shoots. The leaves, which have cuspid margins, are rough, dark green above, and gray, tomentose beneath. The shallow, light gray bark is fissured longitudinally. Teak is a light-demanding tree, and under advantageous conditions growth of the tree is rapid.

The trees usually flower in their fourth year during the rainy season, May-December, and from then on the teak trees seed freely every year. The terminal inflorescence, made up of small, individual white flowers one-fourth of an inch in length, is in the form of a panicle approximately two feet in length. The hard, densely hispid fruit is enclosed in a thin, dry, flask-shaped fruiting-calyx and ripens in the next dry season, February-March. Four, one-seeded pyrenes make up each drupe. Teak is deciduous, losing its leaves in February, the beginning of the dry season. New leaves develop with the beginning of the

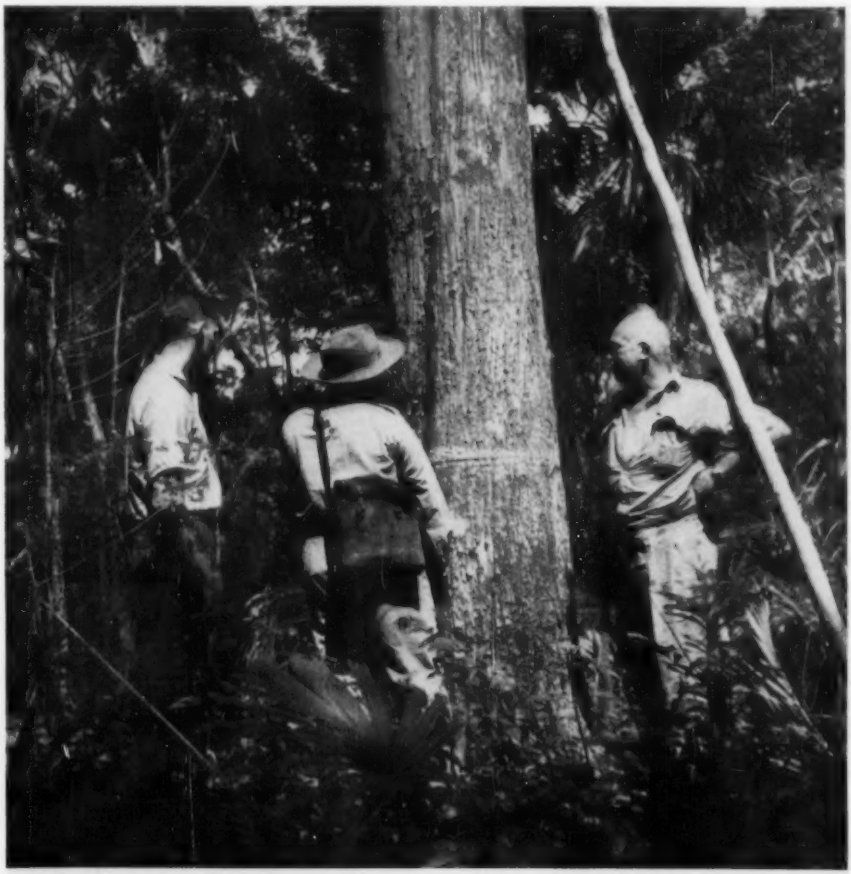

FIG. 1. This teak tree planted in 1928 has a circumference measurement of seven feet, three inches at breast height.

rainy season. Teak coppices vigorously by means of side shoots and callus shoots and retains this power late in life. The tree is resistant to grass and leaf debris fires but is quickly killed by wood fires near the base of the tree (9).

The oily wood of teak is moderately hard and of medium weight, 40-45 pounds per cubic foot, air dried. The heart wood, which begins to form in the sixth year, varies from golden yellow to olive green when freshly cut but darkens with age, turning a rich brown. The white sap wood is small in comparison with the heart wood. Trees 15 years and older have approximately seven annular rings of sap wood. The wood of teak is strong and extremely durable, the heart wood being fairly resistant to decay and termite attack.

Physical Requirements

Climate. Teak thrives best in a moist, warm, tropical climate but is tolerant of wide variations in annual rainfall and temperature. Nearly all of Trinidad is suitable climatically for teak. The annual rainfall at the various plantation sites varies from 70 inches in the south to 120 inches in the north, while the average monthly maximum temperature varies from 86.4° F. in January to 89.8° F. in May. The average monthly minimum temperature varies from 63.6° F. in February to 71.8° F. in September. The relative humidity of the air remains high throughout the year. The climate in Trinidad is seasonal owing to the periodicity of wet and dry periods. The rainy season, from May to December, may be interrupted by the "petite carême", a short, dry spell in September and October. The true dry season extends from January to April, and during this period teak trees lose their leaves (3).

Topography. Teak is not so tolerant of variations in topography as it is of variations in climate. Undulating land is best suited for teak plantations because the slopes usually provide free drainage which is absolutely essential. Flat areas often provide a good site when the natural drainage is supplemented by artificial drainage ditches. Plantations in Trinidad are located mainly on the rolling chain of hills known as the Central Range, which runs diagonally across the center of the island. The undulating dissected peneplain in the southern section of the island also supports successful teak plantations. The Northern Range of mountains with its steep to precipitous slopes is not suited to teak. The flat, dissected alluvial terraces south of the Northern Range and the swampy land around the coasts are also quite unsuited to teak plantations.

Soils. Teak will tolerate wide extremes in soils, provided the soils are drained adequately. Teak plantations showing the highest rate of height and girth growth are situated on fertile calcareous clays, but successful plantations are also found on soils varying from 95% sand to heavy clays. Flat-topped ridges with a hard, compact clay soil as well as flat areas with shallow sand beds overlying clay have proven unfit for teak. The soils on which teak has been planted are extremely acid, ranging from pH 4 to 5.5.

Distribution of Teak Plantations. The major teak plantations are located in three areas on the Island. In the northern section of the Central Range Reserve, plantations have been established at Mount Harris, Tamana, and Mamoral. In the southern section of this Reserve, plantations have been established at Brickfield and at small nearby areas known as Victoria Plantations. In the south, plantations are located in the Southern Watershed Reserve, at Siparia Reserve, Rochard-Douglas Reserve, and Victoria-Mayaro Reserve. Smaller areas are scattered throughout the island in other Forest Reserves. The following table summarizes the total area planted in teak to December 31, 1956 (1).

TABLE I
SUMMARY OF ESTABLISHED TEAK PLANTATIONS AS OF DECEMBER 31, 1956

	Locality	Ages	Total Area in Acres
I.	Southern Watershed Reserve		
	Western Felling Series	0-43	1,800.4
II.	Rochard-Douglas Reserve		
	Morne Diablo Felling Series	0-4	403.0
	Marac Felling Series	0-16	1,038.6
	Rochard-Douglas Felling Series	0-15	652.0
III.	Victoria Plantations	5-28	1,742.0
IV.	Central Range Reserve		
	Brickfield Felling Series	0-16	2,640.0
	Tamana Felling Series	0-30	661.8
	Mt. Harris Felling Series	0-22	220.3
	Mundo Nuevo Felling Series	0-4	170.0
	Old Plantations	28-43	66.8
V.	Siparia Reserve	11-25	177.0
VI.	Victoria-Mayaro Reserve	0-3	85.0
VII.	Cape-de-Ville Reserve	0-4	127.0
VIII.	Tumpuna Reserve	0-6	218.2
IX.	Ortoire-Nariva Windbelt Reserve	0-2	40.0
			10,121.1

Establishment and Maintenance of Teak Plantations

Field Preparation. The preparation of the field for the plantation is done under the Burma taungya system (*7*). Local men sign a contract with the Forest Department under which they are allowed the use of the land rent-free for a period of 15 months to plant certain food crops; in return they must clear the land, keep the land free of weeds, and tend the teak seedlings. The forested area surveyed for the teak plantation is cut by the contractors in January and February. The contractors may buy the logs they cut at the regular royalty rates. The smaller trees are utilized by the charcoal burners who set up their "pits" in the area. The remaining vegetation is usually burned in March or April during the dry season. Trash that remains is gathered in piles, or "boucans", and burned. Burning after clear felling destroys the raw humus but releases potash for the teak seedlings and also makes tending the area easier by killing weedy plants and vines. The teak stump plants from the nursery are planted six feet apart in rows during May and June by the contractors. About 1,210 teak plants per acre are set out. When the contractor signs the contract, he is allotted a one-acre plot in the plantation on which he may plant his food crops: corn, hill rice, dasheen, cassava, and pigeon peas. In the Central Range at Brickfield the contractors are allowed to plant the food crops, usually corn, after the area is partially cleared in October. After the food crop is harvested in April, the area is recleared and burned. Hill rice is then planted along with the teak stump plants. Sometimes a third food crop of pigeon peas can be harvested before the teak trees have overgrown the food crop. This second system is necessary owing to a longer wet season at Brickfield.

The Teak Nursery. Since the initial growth of stump plants, root, and shoot cuttings is much greater than the initial growth of seedlings which have been sown directly from seed, stump plants have a much better chance of survival among the contractor's crop plants. Therefore, teak plantations in Trinidad are all established by stump plants from seedlings grown in nurseries. During the dry season one year before the yearly plantation, or coupe, is to be planted, the area to be set aside as a nursery is cut and burned. A heavy fire is necessary to clear the site completely of brush and weeds. Four foot wide beds running along the contours of the hills are then prepared. In the older plantations

healthy, vigorous trees from which the fruits for planting are to be taken are selected in February and March. The ground is cleared underneath the trees, and young boys are employed to knock down the fruits which are gathered by local women.

In July the fruits are planted six inches apart in the nursery beds. Within a week or ten days after planting, one to four seedlings will develop from each fruit. The seedlings are vigorous, quickly sending up a stout shoot and developing a long tap root. The nursery is usually lightly weeded twice during the development of the teak seedlings. In five months the seedlings are cut back to six inches above the ground to allow development of the slower

FIG. 2. Map of Trinidad showing the distribution of the Forest Reserves in which teak plantations have been established.

FIG. 3. A teak nursery located at the Southern Watershed Reserve. The hut in the center of the nursery was built for the storage of teak seeds before they were planted. The seedlings are three months old.

growing and later germinating seedlings. At the Southern Watershed Reserve nursery the seedlings are again cut back at eight months. At the end of the dry season the seedlings, now thicker at the soil surface than a man's thumb, are pulled up and cut back leaving one inch of stem and six inches of root. This cut-back seedling is known as the stump plant. Large shoots are sometimes cut in half when extra seedlings are needed, but this is not customary practice. Two groups of men are sent into the field to plant the stump plants. With a coffee digger one group digs holes six feet apart; the other group plants the stump plant in the hole and rams the earth around the plant with a cutlass handle. Usually one acre of nursery will supply enough teak seedlings for 30 acres of plantation. In August the teak plants which have died are replaced by new stump plants to keep the plantation fully stocked.

Plantation Management. The teak stump plant begins to coppice one week after being planted and, if set out before the food crops of the contractors, develops rapidly into a tall, vigorous plant. When the crop plants are harvested in November and December, the teak plants usually are one to three feet in height. During the second year of the plantation the teak is inspected, and emphasis in tending the plantation is placed upon eliminating grass, controlling vines and establishing an understory of native woody plants to prevent soil erosion during the dry season when the teak trees are leafless. Native woody plants usually develop from coppice shoots of the original forest trees and from seeds distributed by birds.

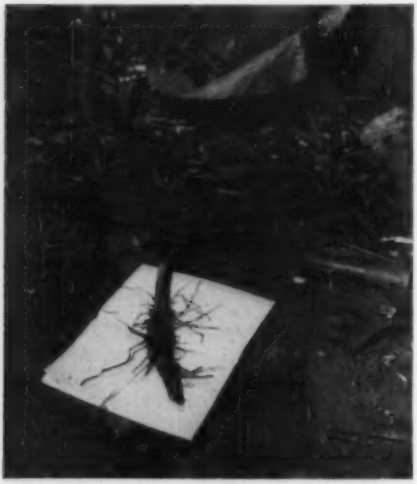

FIG. 4. A teak stump plant ready to be planted in the field.

Since the teak trees planted at six foot by six foot spacings are rather close together, thinning is required in five years. In the plantations during the fourth year after planting, Forest Department workers cutlass the brush in October and November and mark certain trees for felling the next year. Since the early growth of teak is often uniform, the thinning can be made by removing alternate trees in alternate rows. This thinning leaves only one-half the original number of trees planted, or 600 trees per acre having a spacing of 8½ feet by 8½ feet. From January to mid-April the marked trees are cut and removed to the Forest Department's "Brickfield Forest Industries" center for utilization. During the thinning operation all dead, diseased, or dying trees are removed. Good marking is essential at this time to remove the poorer trees and yet keep a relatively closed canopy to prevent side branching of the teak trees. Pruning is also a normal part of the thinning operation of the five and ten year old plantations. The same system of thinning is repeated every five years but with emphasis on removing poorly deformed teak trees. After the fifteen-year thinning operation, approximately 360 trees per acre are left. The yield data for the following table was taken from sample plots in the most successful teak plantations (4). By the time the trees will have reached maturity in 60 to 80 years, approximately 50 trees per acre will be left standing. The teak plantations are being established for a 60 year rotation cycle on the good soils and an 80 year rotation cycle on the poorer soils. At the end of the cycle the trees will be clear cut and the planting program repeated.

TABLE II

YIELD FOR ONE ACRE OF TEAK PLANTATION

Standing crop after thinning					Thinnings	Total Yield
Age	number trees	mean girth at 4′ 3″	mean ht. of dom. tree	solid volume stem wood	solid volume stem wood	solid vol. stem wood
yrs.		inches	feet	cu. ft.	cu. ft.	cu. ft.
5	634	12.5	45	400	107	507
10	286	21.0	63	924	252	1,283
15	224	25.0	67	1,118	287	1,764
20	169	29.0	71	1,295	309	2,250

The Utilization of Teak Thinnings

Processing. In 1955 the Forest Department utilization program for teak

thinnings was given the name "Brickfield Forest Industries". Located at one center in Brickfield are a fencing factory, a sawmill with a Gorwood gangsaw and a resaw, and a hot and cold creosoting plant. The gangsaw is not run in competition with the 95 commercial sawmills in Trinidad because it is designed to cut thinnings up to ten inches in diameter at the butt. The average sawmill cannot handle these smaller trees economically. Larger thinnings are sent to private sawmills on the island. Teak plantations on private estates are relatively young and do not supply any sizeable quantity of teak wood.

Fencing. Split teak fencing utilizes thinnings predominantly from five and ten year old plantations. The teak is split into pickets in the field by the contractors as they thin the young plantations. After the pickets are stacked in the factory, the contractors are paid a standard price for each picket. The operation of the factory is set up similarly to the split chestnut fencing operation in England. The finish-

FIG. 5. A teak plantation established in 1955. The open condition of the young plantation allows the development of grasses underneath the teak trees.

ed lengths of fencing are rolled up and are dried in the open air for three months before they are treated by hot and cold impregnation at the creosoting plant. Impregnation is necessary to improve the lasting qualities of the pickets which are composed mainly of sap wood.

Lumber. Under one roof at the sawmill are the Gorwood gangsaw installed in 1954 and a resaw installed in 1956. The gangsaw cuts lumber in a range of building sizes from two inches by three inches to six inches by six inches. The resaw economically produces four inch by one inch stock from all suitable timber in the slabs cut by the gangsaw. The gangsaw will handle up to 14 foot logs which are taken through the saw by means of a conveyor chain.

Creosote Poles. Since many tropical timbers in contact with the ground are readily attacked by insects and fungi, treatment with some type of preservative is desirable. The easily destroyed sap wood

FIG. 6. A teak plantation established in 1948 as it appears during the dry season. The plantation which has been thinned twice is littered with recently shed teak leaves.

of the teak fencing is impregnated with preservative at the creosoting plant. Six, eight, and ten foot teak poles from the ten and fifteen year old thinnings which are too small to be cut by the Gorwood saw are also treated.

A hot and cold impregnation method is used at the plant. The preservative is a 50:50 mixture of creosote, shipped from the United Kingdom, and dieseline, a gas oil produced on the island.

Utilization of Thinnings. Wood is in great demand in Trinidad. The "Administrative Report of the Forest Department for 1956" indicates that the gross imports of sawn coniferous and non-coniferous lumber totaled 1,212,000 cubic feet. The export of non-coniferous sawn lumber was much smaller, only 19,500 cubic feet. The volume of teak wood produced from the thinnings for the same period was 80,600 cubic feet. Teak is being utilized as fast as it can be cut; the demand is greater than the supply.

Often the teak fences are used around private gardens and homes. They can be seen protecting every school playground and garden in Trinidad and Tobago. The fences are not painted, and the wood weathers to an attractive grayish-brown color.

In 1956 the sawmill produced 148,034 board feet of lumber from 24,462 cubic feet of thinnings. The logs for the sawmill are supplied by contractors who fell the teak thinnings marked by the Forest Department's silvicultural staff. The logs delivered to the sawmill must have a top dimension of six to ten inches underbark, and they must be in 8, 10, 12, 14, or 16 foot lengths. The lumber size, two inches by four inches, is in great demand and usually is bought as it comes from the saw. The sawn teak price is 24 cents per board foot. The revenue from the sawmill exceeded expenditure in 1956 by $5,822.00.*

The lumber produced by the sawmill is bought by construction companies and is used for rafters, studs, purlins, laths, sills, and joists. A furniture factory buys four inch by four inch scantlings and slabs which are used for making collapsible chairs and broom handles. Prior to the establishment of the resaw, slabs were sold by the truck load for $5.00 for firewood. The resaw now cuts the slabs into laths and flooring strips.

From the smaller thinnings, poles cut and peeled in the field by the contractors are stacked for partial seasoning for a period of six months outside the creosoting plant. The number of poles treated in the creosoting plant during 1956 was 12,910. Creosoted poles are sold at the following prices: eight foot lengths, light and heavy weight for $1.00 and $1.50, respectively; ten foot, light and heavy, $1.50 and $2.00, respectively; and thirteen foot, nine inch poles for $3.00. Untreated poles of equal size are sold at one-half the price of the treated poles. The revenue from the sale of the poles exceeded expenditures by $4,995.00.

The demand for both treated and untreated poles and fence posts is high even though "graveyard" tests have indicated that treated fence posts will last 20 years in the ground compared with four to five years for the untreated posts.

* B. W. I. dollar = $0.58 U. S.

The following table summarizes the financial aspect of the Brickfield Forest Industries for the year 1956.

TABLE III

FINANCIAL REPORT OF THE BRICKFIELD FOREST INDUSTRIES

All operation expenses	$56,302.00	Revenue	$54,493.00
* Other expenses	9,067.00	Stock in hand	29,313.00
Net profit	18,437.00		
	$83,806.00		$83,806.00

* Depreciation, royalties accredited to various coupes for timber supplies, salary of monthly paid field staff, etc.

The Future of Teak in Trinidad

In 1942 a Forest Policy was adopted by the Trinidad Government to help the Forest Department best serve the interests of the community. One of the main points of this policy is "that in selected areas the forests should be improved with a view to making the Colony self-sufficient in its timber supplies" (1). The present program of establishing teak plantations in Trinidad is a major step in this direction. By planting 800 acres in teak each year all available land suitable for teak, some 60,000 acres, will have been planted by 1990, the termination year of the present teak rotation plans. At this time the yield of teak wood per year is expected to be not less than 1.5 million cubic feet (10).

Teak in Trinidad is fortunate in having few pests. Birdvine (*Loranthaceae*) infects five year old trees and becomes a problem in the older plantations. The parasite slows down the growth rate of the tree affected and may eventually cover the entire crown, killing the tree. The parasitized trees in the plantations are removed; sources of the infection in the nearby forests are cut out as well. The bachac, or parasol ant (*Atta* sp.), which is a problem in some of the plantations, damages young teak trees by stripping off the leaves. When the ant nests are discovered, they are eradicated by the use of Chlordane and Aldrin. Ground fires in the plantations during the dry season also constitute a problem. Usually the trees are not immediately affected by the fire, but the soil humus is burned and herbaceous and shrubby vegetation is destroyed, leaving the soil exposed and susceptible to erosion during the rainy season.

The future outlook for teak in Trinidad is promising. With few pests to attack the trees and good environmental conditions existing in Trinidad, the teak trees should produce excellent, first quality wood. Comparisons of Trinidad teak with Burma teak show that the former is as good in quality as the latter. Thus, Trinidad can be proud of its new timber resource that was established through the efforts of the far-thinking Forest Officer, Mr. C. S. Rogers.

Acknowledgments

This paper was prepared while the writer was associated with the Imperial College of Tropical Agriculture, Trinidad, on a United States Government Fulbright scholarship. The writer is indebted to John Purseglove, Professor of Botany at the College, and to David Moore, Conservator of Forests in Trinidad, and his staff for their cooperation and kind assistance during the course of this study.

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Investigations On *Simarouba glauca* Dc. In El Salvador

The use of the kernels of Simarouba glauca as a potential source of vegetable oil was first noted in 1939. These kernels produce 62 per cent edible oil under commercial extraction procedures. The trees are polygamo-dioecious, thus creating a selection problem for commercial plantings. A progress report of investigations on the botany, propagation, selection, insect pests, and diseases is given.

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Introduction

The use of *Simarouba glauca* (aceituno) as a vegetable oil crop was first considered near the end of 1939 (11), when it was tested for oil yield and the properties of the oil investigated in a program that included other plants such as *Calocarpum mammosum* (L.) Pierre (Zapote) and *Jatropha curcas* L. (French physic nut). As the corresponding chemical tests proved that the oil of *Simarouba glauca* was suitable for human consumption in all respects, (Tables I & II) a natural second step was to begin propagation of the tree on a larger scale. Toward this end considerable financial outlay and effort were expended, beginning in 1950 when the firm of H. de Sola e Hijos distributed, free of charge, some 188,966 trees of three month old nursery stock. These trees were given to people interested in the cultivation of aceituno in El Salvador, and instruction was provided as to planting and subsequent care (12, 13, 14). Apart from this, the same firm made formal orchard plantings of the tree to the extent of 474 acres (planting distance of 22′ x 22′ = 90 plants per acre) between the years 1948 and 1953. In 1953 when the first of these plantations began to yield fruit, it was found that only 48 to 50% of the trees were productive and that the remainder bore staminate (male) flowers only. Closer examination showed the tree to be not purely dioecious in character, as botanical descriptions had indicated, but, rather, polygamo-dioecious with a considerable range of variance. In view of this fact the present series of investigations was initiated. Much useful advice and a better understanding of the flower morphology of the species was given by the "Centro Nacional de Agronomia" of El Salvador. The initial program of investi-

TABLE I

CHEMICAL ANALYSIS OF ACEITUNO FAT

FREE FATTY ACIDS (OLEIC)	0.06%
IODINE VALUE (WIJS)	53.8
SAPONIFICATION VALUE	191
UNSAPONIFIABLE MATTER	0.40%
INDEX OF REFRACTION AT 25° C	1.4556
TITER	47° C
SMOKE POINT	280° F (138° C.)
CONGEALING POINT (SETTING POINT)	20° C
MELTING POINT—SOFTENING POINT	25° C
CLOSED CAPILLARY	27.2° C
COLOR (LOVIBOND) LIQUID	10 Yellow—0.8 Red
SOLID	Snow White
FLAVOR	Very good, bland
TEXTURE	Excellent
PLASTICITY	Excellent
STABILITY (SWIFT TEST)	100 hours
PEROXIDE VALUE AS REC'D	2.6
(AFTER TWO (2) MONTHS)	2.7
ACCELERATED TEST (3 HOURS AT 105° C) EQUIVALENT TO AT LEAST SIX (6) MONTHS AGE	3.7
CONCLUSION	EXCELLENT KEEPING QUALITIES

TABLE II

BIOLOGICAL TEST OF "NIEVE" VEGETAL FAT

METHOD OF ASSAY: Twenty rats were fed a balanced diet containing 10% of the test material for 30 days. The animals were weighed every 7 days and weight changes noted.

Animal	Initial Weight	Final Weight	Weight Gained	Test Material Consumed
1	144 gms.	170 gms.	26 gms.	26.1 gms.
2	156 "	188 "	32 "	27.8 "
3	120 "	170 "	50 "	25.8 "
4	150 "	190 "	40 "	27.8 "
5	140 "	176 "	36 "	24.9 "
6	142 "	168 "	26 "	25.6 "
7	134 "	190 "	56 "	33.5 "
8	146 "	178 "	32 "	33.5 "
9	150 "	184 "	34 "	27.3 "
10	140 "	196 "	56 "	30.0 "
11	142 "	184 "	42 "	32.4 "
12	156 "	190 "	34 "	27.9 "
13	152 "	200 "	48 "	35.2 "
14	140 "	180 "	40 "	27.7 "
15	140 "	182 "	42 "	30.0 "
16	122 "	150 "	28 "	19.7 "
17	210 "	220 "	10 "	23.9 "
18	138 "	140 "	2 "	17.0 "
19	100 "	186 "	86 "	35.0 "
20	144 "	152 "	8 "	49.3 "

When the test material was fed to 20 rats whose average weight was 143.3 gms. at the rate of 203 gms. per kilogram per month, there was an average weight increase of 36.4 grams.

CONCLUSION: Manteca Vegetal Nieve when fed as outlined above, was found to be non-toxic.

New York,
Jan 31st, 1946.

gation was drawn up by this organization in the year 1950.

Description Of The Species

The following description of the genus and species is given by Cronquist (*7*):

Simarouba Aubl.

"Trees or shrubs; leaves alternate, pinnately compound; leaflets 3-21, firm, offset or rarely some of them opposite; dioecious; inflorescence a complex mixed panicle, the staminate larger and with more numerous flowers than the pistillate; sepals 5, occasionally 4 or 6, united at the base; petals 5, occasionally 4 or 6, distinct; stamens appendaged at the base, 10, occasionally 8 or 12, in the pistillate flowers much reduced or absent; carpels 5, occasionally 4 or 6, borne on a short broad gynophore or disk, weakly united, with a short common style and divergent stigmas; the staminate flowers with the gynophore present but the carpels absent; ovules 1 in each carpel; fruit of several distinct drupes."

Key to the Central American Species (2). (Based on the key to the genus, by Cronquist, (*7*)).

Petals usually less than 4.5 mm. long; anthers less than 1 mm. long; veins on the lower surface of leaflets obscure or visible as furrows. A tall tree, found in coastal rain forests. Rare (not known from El Salvador). *S. amara.*
Petals usually more than 4.5 mm. long; anthers more than 1 mm. long; veins on lower surface of leaflets usually evident as distinct dark lines. A small to medium-sized tree, found on semi-arid and rocky lands at low and intermediate elevations. Very common in El Salvador and adjacent territory. *S. glauca.*

Natural Distribution and Nomenclature. *Simarouba glauca* is found under a wide range of conditions and at low to medium elevations from Southern Florida to Costa Rica, including the following islands in the Caribbean: The Bahamas, Jamaica, Cuba, Hispaniola and Puerto Rico. It is known under a variety of common names: aceituno or olivo in Costa Rica; aceituno or negrito in Nicaragua; negrito in Honduras; chapascuapul, jocote de mico, pasac or zapatero in Guatemala; pasac in Mexico (Oaxaca); palo blanco in Cuba; tree of heaven in Florida; mountain damson in Jamaica; and aceituno in El Salvador.

In El Salvador the tree is commonly found at elevations ranging from sea level to 3,000 feet, but the more heavily populated natural stands are encountered at medium elevations of 1,500 to 2,500 ft. It is a small to medium sized tree seldom exceeding 60 to 65 feet in height with a maximum trunk diameter of approximately 20 inches at breast height. The tree is common throughout the country, at the elevations mentioned, and frequently becomes the dominant species in the more

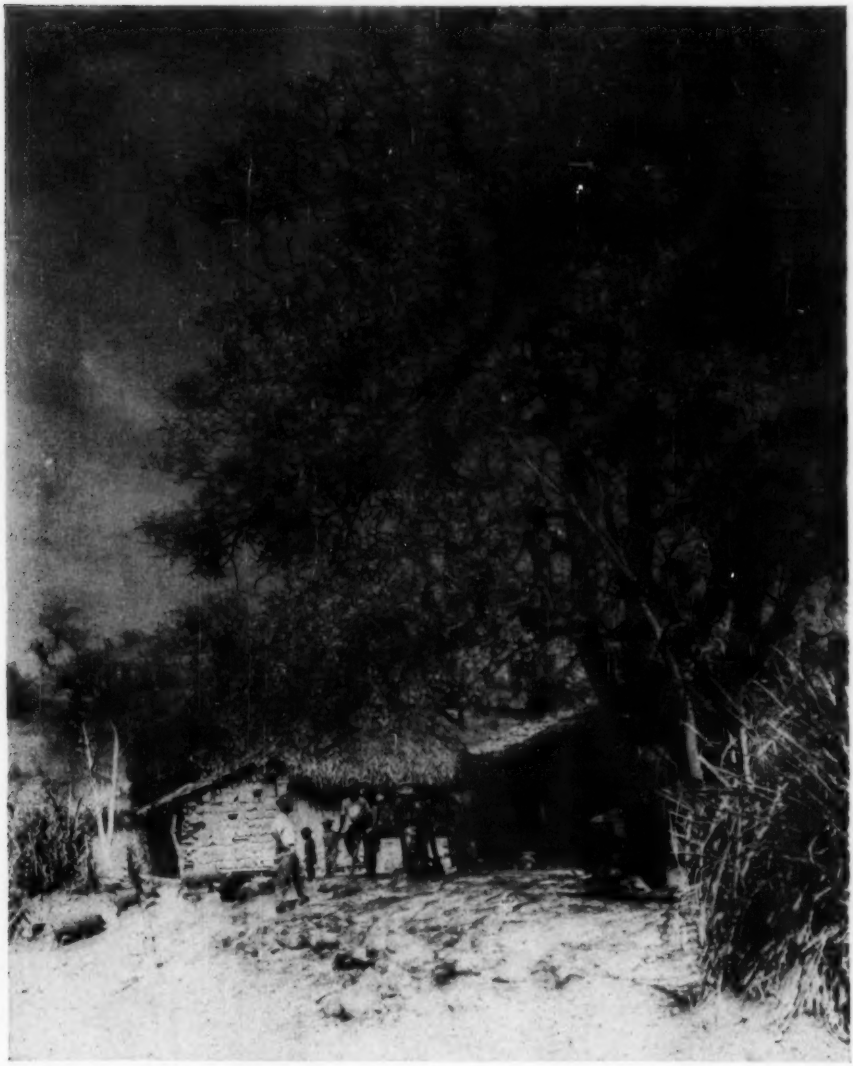

FIG. 1. Typical door-yard specimen of aceituno near Santa Clara, Dept. San Vicente, El Salvador. This tree was credited with an annual yield of over 200 lbs. of dried fruit. (Photo: Paul H. Allen).

arid regions of the following departments (states) of the country: Cabañas, Chalatenango, Morazán, San Miguel and San Vicente. Although not actually cultivated before 1948, as mentioned earlier, it is of interest to note that, in rural areas, people are careful to protect the small trees and allow them to grow in pastures and cornfields when these are being cleared for cultivation. Volunteer plants growing along roadsides are also commonly encountered and are left to grow unharmed. Aceituno is a favorite door yard tree in the rural areas (Fig. 1). Local uses of the tree include: a crude household soap made by boiling the fat from the kernels and mixing with wood ashes; a febrifuge made by extracting the astringent juice of the bark; a crude remedy for diarrhea, particularly in children, is made by collecting the same juices of the bark adding them to the juice of mango bark, with the normal dose being one teaspoonful given three times daily. The somewhat astringent but semi-sweet pulp which surrounds the seed of the aceituno is eaten mainly by children; occasionally one will see the fruits for sale in the local markets during the month of May. On May 3, "Día de la Cruz" (Day of the Cross) is celebrated. Aceituno finds favor as one of the fruits used to decorate the cross which has a prominent place in all Salvadorean homes on that day (Fig. 2). Since it is the custom that all visitors to the home on May 3 be given their choice of fruits from the decorated cross it is probable that the very wide distribution of this tree may, in part, be due to this local custom. It is true that there seems to be some relationship between its distri-

TABLE III

DISTRIBUTION OF FLORAL TYPES IN ACEITUNO—YEAR 56/57

Locality	Elev. In Feet	Age Of Trees	Number Of Trees			
			Pistillate	Staminate	Andromonoecious	Total
La Cabaña	900	6 Years	83	58	62	203
Bonaire	1,760	6 "	450	448	10	908
Altamira	2,800	9 "	42	30	4	76
Km. 124	1,300	9 "	503	462	363	1,328
Zaprivas	500	4 - 9 "	257	192	76	525
Jocotillo	1,200	8 "	142	136	80	358
El Blanco	350	5 "	45	30	25	100
Totals			1,522	1,356	620	3,498

TABLE IV

THE QUANTITATIVE RESULTS OF TABLE III EXPRESSED IN PERCENT

Locality	Elev. In Feet	Age Of Trees	Number Of Trees			
			Pistillate	Staminate	Andromonoecious	Total
La Cabaña	900	6 Years	40.89	28.57	30.54	100%
Bonaire	1,760	6 "	49.56	49.34	1.10	100%
Altamira	2,800	9 "	55.26	39.47	5.27	100%
Km. 124	1,300	9 "	37.87	34.80	27.33	100%
Zaprivas	500	4 - 9 "	48.95	36.57	14.48	100%
Jocotillo	1,200	8 "	39.66	37.99	22.35	100%
El Blanco	350	5 "	45.00	30.00	25.00	100%
Average:			45.31	36.68	18.01	100%
Summary of Two Years Records		1955/56	40.90	38.45	20.65	100%
		1956/57	45.31	36.68	18.01	100%
	Average:		43.10	37.57	19.33	100%

FIG. 2.—Typical decorated cross which is a feature of most Salvadorean homes on May 3rd, "Día de la Cruz". Note the ripe aceituno fruits.

bution and population density. Aceituno surveys, made in areas of the country only recently opened up by new highways and sparsely populated, tend to bear out this fact.

Both the male and hermaphroditic trees quickly become known as "Machos" (males) among the local people, since the hermaphroditic trees bear little or no fruit. When these become sufficiently large for their lumber to be utilized, they are felled and used as yokes for oxen, as utility furniture, as boxes, and as fuel. There is a small market for the larger logs for the manufacture of matchboxes, but the wood is considered, locally, to be rather brittle for matches themselves. Lamb (15) notes that the working qualities of the wood are rather similar to those of American bass wood or white pine. Some tests (6) have been carried out using aceituno lumber as pulpwood, but since the wood was mixed with 8 or more other tropical species, no specific conclusion on the pulping qualities of aceituno can be drawn.

As mentioned previously, the tree prospers in the more arid regions of the country where the land is largely marginal for other types of agriculture. In these areas, during the dry season (November to April), the tree is most conspicuous with its dark green, shiny foliage, in sharp contrast to the normally leafless condition of many of the other arborescent species and the desiccated or burned appearance of the herbaceous vegetation.

FIG. 3. Five year old aceituno orchard on marginal agricultural land. (Photo: Paul H. Allen)

Uses

Kernels. Aceituno fruits (Fig. 4) are similar in size and shape to the European olive, hence the common name. The outer pulp, or mesocarp, is generally two to three millimeters thick when fresh, covering the seed itself which is some 20 millimeters long and 12 millimeters wide. The thin, brittle endocarp is easily broken and comprises 7.0% of the dried fruit; the enclosed kernel is about 1.5 centimeters long and .75 centimeters wide, greenish-yellow, brittle, oily to the touch, and easily pressed between the fingers (Figs. 5 & 6). This kernel contains between 55% and 65% fat at 14% moisture content (16). Recent experiments, however, have indicated that oil yield may be as high as 75% in some cases when analyzed on a dry basis (TableV). Test runs on an industrial

TABLE V

ANALYSIS* OF ACEITUNO KERNELS SHOWING OIL CONTENT (EXPRESSED AS PERCENTAGE OF WHOLE KERNEL)

Limits Of Fluctuation	75.00%	- 64.14%
Difference	10.86%	
Average based on 107 Tests	69.42%	
Tree Showing Lowest Yield, No. 17, Lote #1, Km. 124 —San Miguel	64.14%	
Tree Showing Highest Yield, Inj. C.N.A. Lote #3, Los Mangos—Finca Bonaire	75.00%	
White Variety based on 25 trees	69.65%	
Black Variety based on 25 trees	69.49%	
Arbol Brannon	67.30%	
Luisito Blanco	69.10%	
Luison Negro	66.83%	

* Dry Basis.

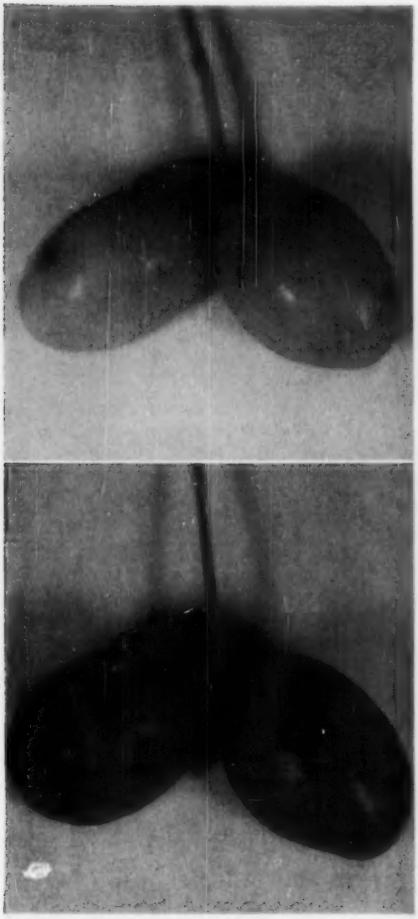

FIG. 4. Aceituno fruits, white form above, black form below. (Photo: Paul H. Allen)

scale have shown oil output to be approximately 62% of the kernel, by weight. Some 1,230,000 pounds (average for the years 1953-1957) of aceituno kernels are processed annually in the "Eldorado" factory of H. de Sola e Hijos, in San Salvador. More than 99% of these kernels are harvested from wild or semi-protected spontaneous stands of aceituno while the orchard plantings of the firm are responsible for only .7% of the total.

Oil Extraction. For the large scale factory operation Doctor G. Paggi, Technical Adviser for the industrial operations of H. de Sola e Hijos, has found the fol-

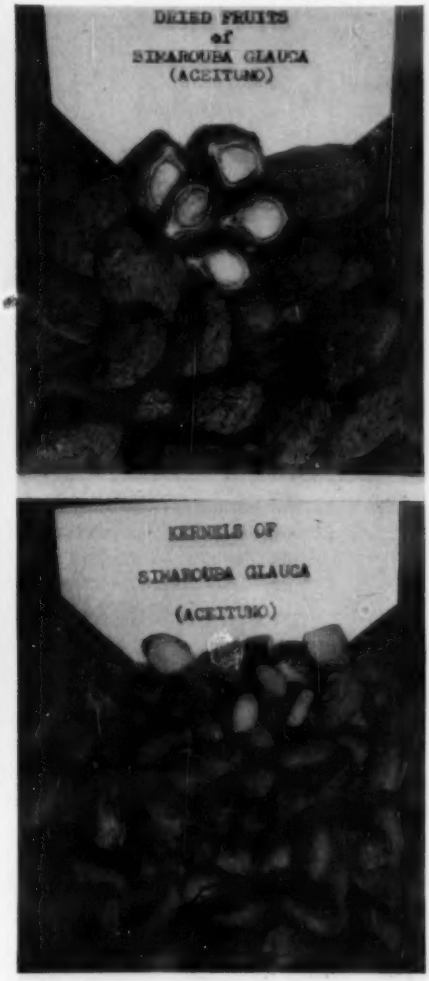

FIG. 5. (Upper) Dried fruits of aceituno with remnants of pericarp attached. Sectioned fruits at base of label expose cross-section of pericarp and kernel. (Photo: Paul H. Allen)

FIG. 6. (Lower) Kernels of aceituno. Cross-sectioned kernels at base of label. (Photo: Paul H. Allen)

lowing method to give the best results for the extraction of aceituno oil "fat" from the shelled kernels:

"The machine used is a continuous screw press, in this case an Anderson duo expeller, and it has been demonstrated that when the kernels are mixed with 20% to 35% of the aceituno hulls, or in cases where this is not available, with an equal proportion of aceituno press cake, that there is a greater recovery of oil from the kernels. It is of interest to note that the present method of using either broken hulls or press cake as a "cushion" to allow greater extraction leaves only 7% to 8% of oil in the press cake, whereas crushing of the pure kernels generally leaves 15% of oil in the resulting press cake. Previous to passing to the expellers the kernels are heated to 88° centigrade in the conditioner which is attached to the expeller. Factory recovery of oil from this method has been found to be in the region of 62%, by weight, of the whole kernel. Up to the present time aceituno for oil extraction has been purchased in the form of the kernel with its shell (endocarp) removed, but experiments are now under way, in the same factory, to devise a method whereby the dried fruits may be shelled mechanically by means of a bar huller of the type usually used for cottonseed, the excess hulls being then removed by pneumatic separating devices and screens. It has been found that the percentage of hulls in relation to dry fruit may be reduced from 70% to 35% by this method. This latter figure is considered adequate for the pressing process as has been shown above."

Composition and Uses of Aceituno Fat. The crude oil after extraction (pressing) is handled much the same as other vegetable oils; i.e. it is neutralized by a weak alkali solution, washed, dried, bleached, filtered, and deodorized. After deodorization, the oil is run over an Albright-Nell chill roll at about —12° C. and is pumped into containers which range from drums of about 400 lbs. to individual carton cups of 1 lb. content, ready for the consumer.

It is pertinent to remark that no hydrogenation is required in the manufacture of this edible fat, and the final product remains firm up to temperatures of 27°-28° C., due to the rather narrow melting point range of the various glycerides. This means that it can be marketed in warm climates, such as that of El Salvador, without any need for refrigeration, since the product will stay solid indefinitely at ordinary room temperatures.

TABLE VI

COMPOSITION OF ACEITUNO FAT*
(EXPRESSED AS PERCENTAGE OF GLYCERIDES)

Constituent	Per cent	Constituent	Per cent
Oleic	59.1	Diene	0.13
Linoleic	3.3	Triene	0.002
Linolenic	0.35	Saturated	31.7

* Determined at the Southern Regional Research Laboratory, Bureau of Agricultural and Industrial Chemistry, U. S. Department of Agriculture, New Orleans, La. A.O.C.S. Method Cd 7-48.

This product, marketed under the trade name of Manteca Vegetal "Nieve", keeps for well over six months with no refrigeration, as shown by many trials carried out under controlled conditions and in differing climates. The product has remained stable when shipped in railway cars to sea level, where extremely high temperatures (up to about 40° C.) obtain. Although partially liquified under such conditions, it rapidly resumes its solid state when brought back to atmospheric conditions under 27° C. "Nieve" has been successfully marketed in El Salvador during the last ten years, and demand has steadily exceeded supply (11).

Table VI shows the composition of aceituno fat expressed as percentage of glycerides, as given by Dr. Mario Lewy van Severen (16).

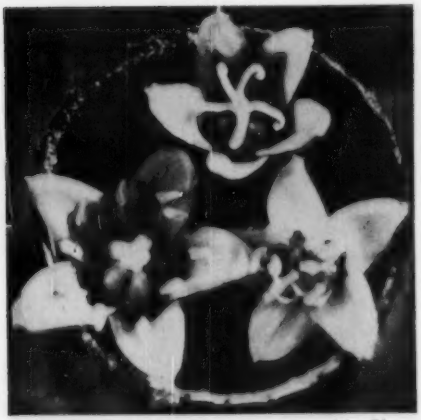

FIG. 7. The three floral types found in *Simarouba glauca* DC. Center: pistillate flower; lower left, hermaphrodite flower; lower right, staminate flower. (Photo: Paul H. Allen)

Aceituno Press Cake. The press cake resulting from the milling operation has a strongly bitter flavor and is toxic to humans and animals. It contains, however, a very high percentage of protein, approximately 64% by weight. Project 6 of the present investigation has been set up to see if this material can be used as cattle feed, after the extraction of the toxic element, and to determine whether this element might be marketed separately.

At present the press cake is being utilized as an organic fertilizer, and used in this fashion the values of press cake may be expressed as follows: nitrogen (N) 7.7%, phosphorous (P) 1.07% and potash (K) 1.24%. There are also traces of calcium, magnesium, and sodium. Being bound in organic matter the nitrogen release is gradual, a factor which is favorable to most crops growing in the high rainfall areas of the tropics. The use of aceituno press cake as a fertilizer has given good results on coffee, sugar cane, cotton, and corn (maize) (11).

Planting Procedure and Costs

With the present investigation planting procedures are now being more widely studied under the general title of propagation, since vegetative reproduction techniques call for a greater range of materials and methods. However, a short resumé of the methods (13) used to establish the existing plantations of seedling trees in the years 1948-53 may be of interest as accurate costs are also available. The seeds were sown on raised seedbeds of well worked soil much like those commonly used for truck crops such as cabbage and tomatoes. The seeds were placed in rows which were nine inches apart and almost touching within the row, at a depth of approximately one inch. These beds were covered with a mulch of dry grass or sliced banana stems to conserve moisture and reduce watering. Sowing commenced during early April, and soon after germination the plants were thinned out within the row to give a distance of nine inches, one from the other. Germination of aceituno seed normally occurs within 26 to 35 days. The plants reached sufficient size to be moved to the field within six to seven weeks from the date of sowing. Planting distances varied between 22 x 22 feet and 25 x 25 feet, and subsequent experience proved the latter to be the best spacing in most cases. After lining, planting holes (18″ x 18″ x 18″) were prepared; these were filled with the best top soil to be found in the adjacent area; care was taken to remove stones, etc. Transplanting commenced as soon as the rainy season was well under way (approximately mid-June) and continued until August. Plants were moved with a ball of soil (6″ x 6″ x 9″) from the nursery. No irrigation was given after field planting.

Cultivation comprised, on an average, three cleanings a year to remove weeds within a radius of 20 inches from the plant, care being taken not to damage the plant with the *cuma* (native knife used for this purpose) while the operation was being carried out. Present stands of aceituno have shown these methods to be largely successful and have been accomplished at the following costs:

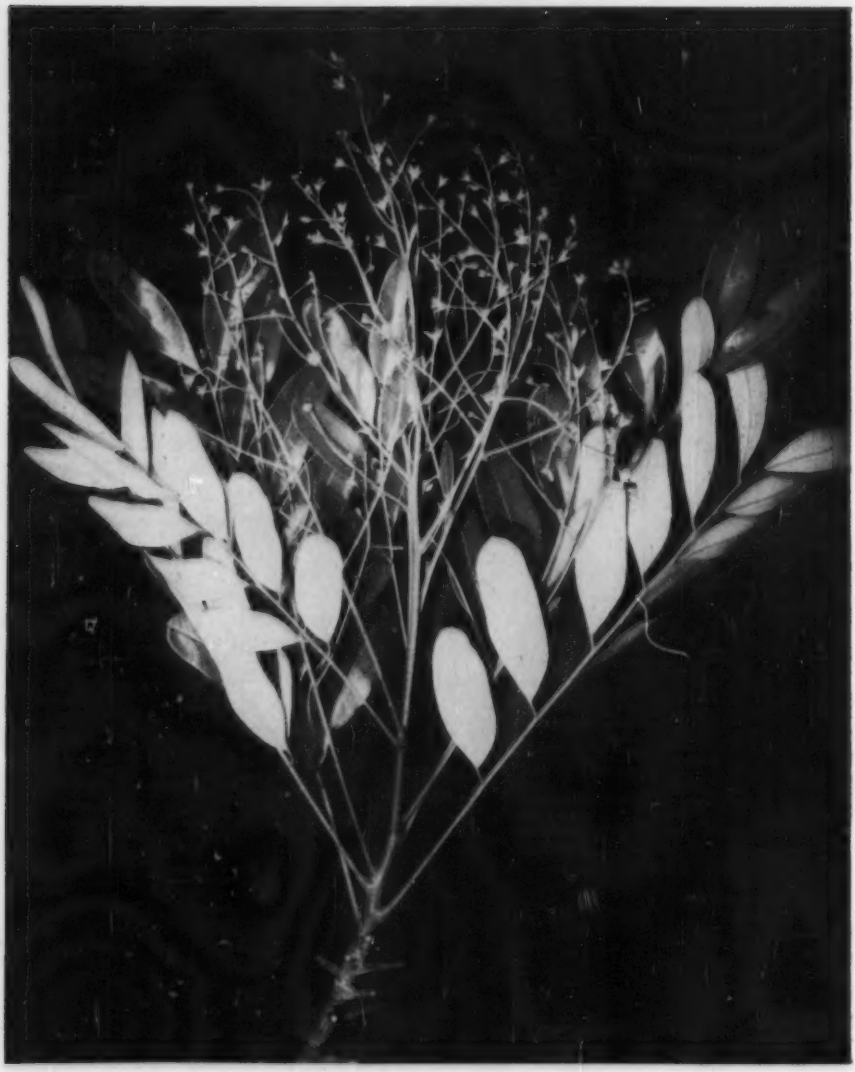

FIG. 8. Typical panicle of pistillate flowers. (Photo: Paul H. Allen)

(Figures given are per plant, in U. S. currency)

1.	Nursery costs	$0.080
2.	Staking and lining	0.048
3.	Holing	0.154
4.	Filling Holes	0.032
5.	Planting	0.042
6.	Local Freight Charges	0.026
7.	Cultivations (4 during first year)	0.100
8.	Miscellaneous	0.026
9.	Administration	0.016
		$0.524

Costs per plant during the next five years, i.e. until the trees came into bearing, are considered to be approximately $0.35 (U. S. currency) annually, giving a total cost of $2.27 per plant up to and including the sixth year. At 90 trees per acre this would involve an initial outlay, cost of land excluded, of $204.30 per acre to bring an aceituno plantation into bearing.

As has been stated earlier, such a plantation of seedling trees is most liable to produce only 48% to 50% female (pistillate) trees. Since seedling trees commence flowering at six to eight years, it is clear that some means of pre-determining the flower sex *before* the plants produce flowers and, ideally, before field planting is carried out should be investigated. At present, vegetative propagation is the best method of assurance of the correct sex.

Production

During the past three years (1956, 1957, and 1958) production records have been obtained from 104 trees growing in formal orchard plantings with an age range from six to twelve years and also from three mature native trees estimated to be between 18 and 25 years old. The information obtained from the 104 trees under control has been the basis for the production estimates of aceituno seedling trees as given in Table VII. Of the three wild trees, which have been selected as the potential source of high yielding clonal material, two (Brannon and Luison) have consistently given annual yields in excess of 200 lbs. of dried fruit per tree during the three-year period.

As will be seen from Table VII, adverse soil conditions seem to be the only environmental factor showing some influence on maturity in seedling trees, i.e., yield from trees grown at Jocotillo begins only in the eighth year whereas all other plantings begin to bear between the fifth and sixth year, despite differences in elevation.

Production results from grafted trees have been most encouraging, but sufficient data is not yet available for a critical analysis. Further work on this phase of the project is now under way, and results will be given at a later date.

Progress Report (to June, 1958)

The present investigation is divided into the following projects:

Project 1) Botanical study
" 2) Propagation

TABLE VII

PRODUCTION* ESTIMATES — ACEITUNO SEEDLING TREES

LOCALITY	ELEV. IN FEET	AGE OF TREES IN YEARS 4	5	6	7	8	9	10	11	12
Km. 124	1,300	1.0	8.5	9.0	10.2	10.35	13.93	17.8	19.50	22.1
Jocotillo	1,200	—	—	—	—	.6	3.0	6.8	7.2	8.5
El Blanco	350	—	.8	4.25	6.2	10.35	12.2	15.0	16.05	17.3
Zaprivas	500	.3	2.5	3.0	5.8	10.2	12.3	14.6	17.2	19.4
Bonaire	1,760	3.8	4.2	16.25	17.15	19.23	20.5	21.23	23.4	25.02
La Cabaña	900	—	—	.05	1.5	5.2	8.4	10.6	13.2	15.5
Altamira	2,800	—	—	.08	1.7	6.1	12.19	14.35	16.10	18.91

* Pounds Dried Fruit.

" 3) Adaptation studies
" 4) Selection of high yielding trees
" 5) Insect pests and diseases
" 6) Studies of the toxic element found in the press cake of aceituno kernels.

For the purposes of the projects 1, 2, 3, 5, and 6 enumerated above, the entire 474 acres of formal plantings made by the firm of H. de Sola e Hijos have been available for study. These plantings are distributed as follows: three in the central region and four in the eastern region of the country, making a total of seven plantings ranging in elevation from 350 ft to 2,800 ft. above sea level. A discussion of the soils, climate, and native stands of aceituno follows.

Soils. Soil conditions vary in each of the seven locations, and the following description of each soil type has been supplied by Dr. Clinton Bourne of the Servicio Cooperativo Agrícola Salvadoreño-Americano; (U.S.O.M.):

"The principal zonal soils on which aceituno trees occur belong to groups of Latosols characterized by dark-colored granular surface soils and red or reddish brown, clay subsoils which range in structure from granular to blocky, inconsistence from friable to very firm and plastic, and in permeability from moderate to slow. There is an evident accumulation of manganese. The parent material may be

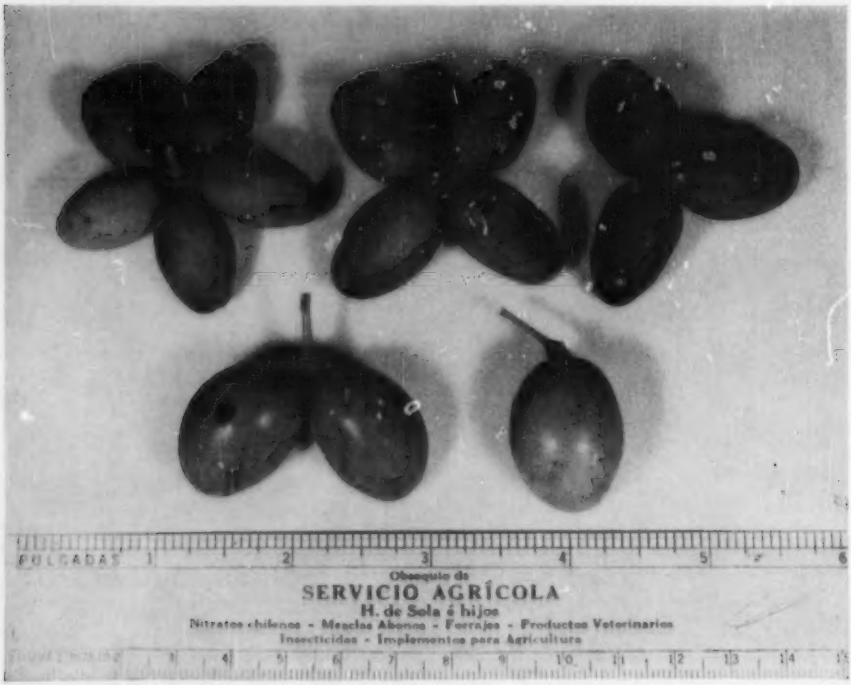
PULGADAS
Obsequio de
SERVICIO AGRÍCOLA
H. de Sola é hijos
Nitratos chilenos - Mezclas Abonos - Forrajes - Productos Veterinarios
Insecticidas - Implementos para Agricultura

FIG. 9. Aceituno fruit clusters showing (from left to right and top to bottom) how five, four, three, two, or individual carpels may be ripened on the gynophore of the pistillate or hermaphrodite flower. One or two mature carpels are most commonly found in the hermaphrodite form. (Photo: Paul H. Allen)

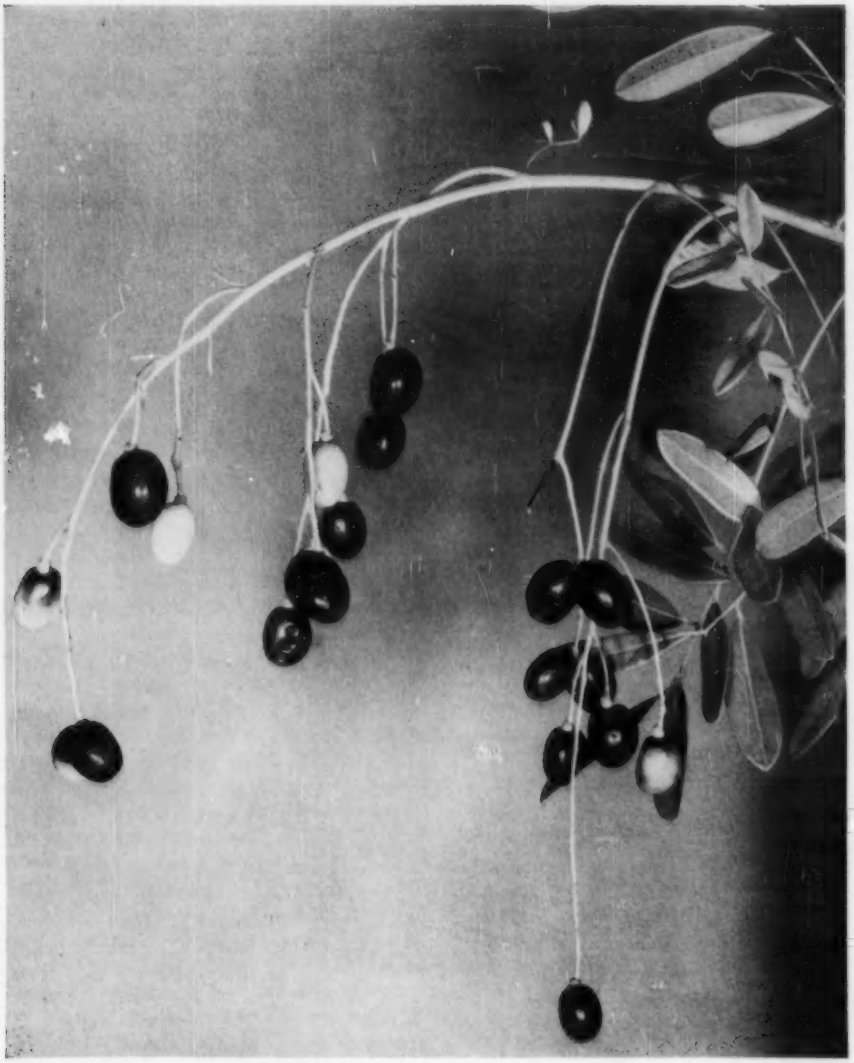

FIG. 10. Aceituno negro. Typical fruit cluster of andromonoecious tree. (Photo: Paul H. Allen)

weathered to depths of tens of feet. Where it was originally hard rock, such as lava, reticulate mottling and concentrically weathered boulders are common. Reaction of the surface soils is slightly to moderately acid. Results of analyses for available phosphorous and potassium are frequently moderate to low.

"Though not yet clearly established, it is possible that Red and Yellow Podzolic soils occur; however, these are at elevations above 3,000 feet where aceituno apparently is not well adapted.

"Other important groups of soils in which aceituno is grown include deep, permeable loamy Regosols and Andosols of low volume weight developed in volcanic ash; and stony Lithosols with fractured substrata. The latter are generally sufficiently weathered to be classified more properly as Lithosols intergrading to Latosols. All of these soils are capable of deep moisture storage. Reactions are mostly slightly to moderately acid. Available phosphorous and potassium is frequently moderate to high.

"Groups of soils in which aceituno has been observed to do poorly include black plastic clays classified as Grumosols, and Lithosols developing in cemented volcanic tuff or lava with few fractures or pockets of weathered material for the deep storage of moisture.

"The soils at the sites of the experimental plots of aceituno are representative of the Zonal Latosol groups and the Regosols. The sites on Latosols (Jocotillo; Km 124; El Blanco and Zaprivas) occur in the vicinity of San Miguel at elevations of 300 to 1,600 feet. The site at El Blanco has soils characteristic of the "friable" Latosols. It occurs on an old valley floor so completely dissected that it is now a complexly rolling, more or less stony, area of hills and swales. The parent material is basic lava—strongly weathered to 5 feet or more. The surface soil is dark reddish brown, friable granular clay loam, 3 to 6 inches thick. It is underlain by yellowish-red, fine blocky to granular clay with the friability of a clay loam. This becomes reticulately mottled with reddish yellow and contains casts of the original rock at depths below about 20 inches. The soil is moderately permeable and has good moisture holding capacity. The deep substratum is usually at field capacity by the end of the rainy season. The single profile analyzed was low in available phosphorous and potassium. It had an organic matter content of 8.5% and pH of 6.1. Except for a few sharp knobs of shallow Lithosols the site may be considered productive for aceituno.

"The soils on the sites at Finca Zaprivas and Km 124 differ from those at El Blanco in being developed in deep deposits of weathered volcanic ash. The former is on a slightly irregular gentle footslope of less than 4% gradient. The subsoil is somewhat more compact and plastic but the surface soil is darker and deeper, being as much as 30 inches thick in the slight swales. The site is productive for aceituno. At Km 124 the soils have similar but less strongly developed profiles. The surface soils are dark loams and clay loams, the subsoils brown clay loams and the substrata loams. The site is on undulating to hilly topography resulting from the mature, parallel dissection of a gentle plain. It, too, is productive for aceituno.

"The site at El Jocotillo occurs on a submaturely dissected plain so that it is an association of gently sloping ridges and steep hillsides. The parent material is volcanic ash similar to the two previous sites. However, the soil on the ridges has a plastic, slowly permeable, dark reddish brown, clay subsoil extending to depths of 3 to 4 feet. The surface soil is acid, having a pH of 5.1. Soils on the sidehills grade from that of the ridges to Latosol-Regosol intergrades. This site is definitely less productive for aceituno than the sites previously described.

"The sites representative of the Regosols, and by inference the Andosols, occur in the general vicinity of San Salvador at

FIG. 11. Typical fruit cluster of black aceituno from a pistillate tree. Tree of relatively low yield and not worthy of selection. (Photo: Paul H. Allen)

Altamira with an elevation of 2,775 feet, at Bonaire with an elevation of 1760 feet, and at La Cabaña with an elevation of 900 feet.

"The site at Altamira occurs on mountainous terrain with dominant slopes of 20 to 40 percent. The soil is white volcanic ash of pumicite with little indication of soil development other than for the darkening of the surface layer by organic matter. It is relatively fertile, rapidly permeable and has a moderately high moisture holding capacity.

"The site at Bonaire is in a gently sloping narrow side valley of about 5% gradient. The soil is a dark, deep loam intermingled with a moderate amount of cobbles and boulders. It is equally as fertile, permeable and retentative of moisture as the site at Altamira. Because of its more favorable climatic position it is more productive for aceituno.

"The site at La Cabaña is on a broad nearly level valley floor or terrace with an alluvial soil consisting of a very dark grayish brown sandy loam surface soil 8 to 12 inches thick over white loamy sand derived from pumicite. Indurated tuff occurs at 5 to 15 feet. However, the site is at the edge of a deep channel so that drainage is good. Permeability of the soil is rapid, moisture holding capacity and fertility moderate. The site is productive for aceituno".

Climate. Other environmental factors vary only slightly with a natural reduction (of approx. 5° C.) in day temperatures at the highest elevation (at Altamira) of 2,800 ft. Average day temperatures at the seven locations vary between 21.5° C. and 28.6° C. Annual rainfall with an average of 1,769 millimeters for properties in the central region and 1,833 millimeters for those in the eastern region varies but little and the distinct dry season of six months (November to April inclusive) is common to both regions.

Native stands of aceituno. Only in the case of project 4 "The Selection of High Yielding Trees", has a wider use been made of the natural stands of aceituno to be found in the country. This has been done to utilize the greater age (limit) to be encountered in these stands where fine specimens of 25 years old or more give a better indication of potential yield to be obtained from adult trees. In the case of the botanical study, particularly in relation to the three floral types which have been encountered, the detailed inspection which has been the basis of this study has been carried out entirely within the above-mentioned plantings, but the results have been checked against trees in native stands to ensure that cultivation practices have not exerted any influence in this respect.

1. Botanical Study

Of the literature references available (1, 7, 19, 20, 24, and 25) that of Cronquist (7) in his studies of the Simaroubaceae most closely corresponds to what has actually been found after (annual) examination of some 3,500 trees in the field over a period of three years (Table III). More recently Allen (2) has modified the description given by Cronquist to include the additional characteristics of the species as found during this investigation. Field studies have shown that although the literature refers to the species as being dioecious the tree is, in reality, polygamo-dioecious (Fig. 7 shows the three floral types encountered). Also, as found in El Salvador, there are two distinct forms of aceituno: the black and the white. This local designation refers to the color of the mature fruit; the black form is deep purple to black when ripe and the white form whitish-yellow and more or less translucent (Fig. 4). Apart from fruit color, it is possible to distinguish the two types from the young growth tips which, in the case of the black form, usually show a distinct red pigment on the leaf rachis whereas in the white form it is light green. Botanically

FIG. 12. Fruit cluster from grafted tree (black form) or aceituno. Scion material was selected from high yielding tree (Arbol Cañas). (Photo Paul H. Allen)

these two forms have never been distinguished, and it is quite possible that the differences in the characteristics mentioned are not sufficient to warrant such action. Nevertheless, from a horticultural viewpoint, and for the purposes of the present investigation, such a division has been found necessary to study behavior and characteristics of the two forms in relation to aceituno as a potential vegetable oil crop to be grown on a commercial basis. The principal object of this botanical study has been to establish, on the basis of detailed flower studies, the flower types which actually exist in *Simarouba glauca*. On the basis of the material seen in El Salvador it would appear that the floral variation may be limited to the following types:

a) Pistillate form (female trees)
b) Staminate form (male trees)
c) Andromonoecious form; i.e., trees having hermaphroditic flowers and also purely masculine flowers on certain branches of the same tree.

Since it is considered that the dioecious state is the more advanced and the hermaphroditic the more primitive in the evolutionary series, monoecious types may be said to represent a waystop along this very gradual evolutionary path, so that in *Simarouba glauca* we have a species which may be undergoing this change to a fully dioecious state. This point is of major importance when we come to the selection of material to be used for vegetative propagation of this species (Table VIII). It is also interesting to note that in the purely staminate flowers it is not possible to distinguish even the most rudimentary signs of an ovary, while in the case of the pistillate flowers, it is always possible, after removing the five petals, to distinguish short rudimentary stamens. These vary in length and may be reduced to shortened filaments, while in the most strongly developed cases actual anthers may be present. These anthers are, however, entirely nonfunctional. This latter type has led to the impression, in one or two cases, that gynomonoecious forms were present, but closer inspection has always shown the stamens to be without pollen and the flower to be purely pistillate.

Close observation of the three floral types has also shown that, while the stigma of the pistillate form exhibits five fully developed, radiate arms above the five carpels, this is **not** the case in the hermaphroditic form where the stigma remains fused and much reduced on a shortened style (Fig. 7). This probably explains, at least in part, the fact that only one or two carpels per flower ever reach maturity in the hermaphroditic trees, while in the pistillate types between three and four fruits are normally formed on each gynophore, and it is not unusual to find five completely formed carpels (Figs. 8 and 9). This seems to indicate that the fused pistil in the hermaphroditic form becomes partly sterile or, at least, that its normal

TABLE VIII

STANDARDS FOR TREE SELECTION OF ACEITUNO

Flower Type	Estimated Crop	Fruit Size	Weight of Kernel (Dry Basis)	Oil Content %	Tree Form
Pistillate*	150-200 Lbs. Dry Fruit For Adult Trees	Dry Fruit With Endocarp 2 cm. x 1 cm. Kernel 1.5 x .75 cm.	Not Less Than 30%	Not Less Than 69% (Dry Wt. Basis)	Well Formed Crown And Bearing Surface

* It is important that all trees having any tendency toward bearing perfect (hermaphrodite) flowers be eliminated, even though these may occur only on certain branches. For this reason it is essential to check flower type on all branches of the tree when selection is made.

function is impeded. It is interesting to note that a similar condition has been observed by Brooks (5) in his investigation on *Olea europea* L.

Also, according to the literature, a notable characteristic of such plants is frequent lack of constancy within the species as to floral types and their distribution (21, 22, and 23). In aceituno we have discovered three different categories of floral arrangements. Any study of the propagation of aceituno by sexual means would be a long range one due not only to the above considerations but also because of the length of time (five to eight years) between seed germination and first flowering. With asexual propagation stability of inflorescence types and sexual character data may be obtained in from eighteen months to three years.

The above discussion is given to emphasize the need to propagate by asexual means. Selecting material carefully from well-known gynodioecious trees which have consistently borne good crops for a number of years, followed by a rigid series of inspections of this material to insure that the development on the root stocks gives the desired result with no morphological change in the scion material, is the most desireable procedure.

FIG. 13. Aceituno nursery with seedlings of the black form at a suitable age for grafting (ten months).

Table III shows the number of trees of each floral type in a total of 3,498 trees studied during the years 1956-57. Table IV gives the same information on a percentage basis and indicates that, if we consider the andromonoecious trees to be fruitful, the percentage of producing to non-producing trees in any seedling stand would be 62.43% against 37.57%. (aver-

age for the records of two years). However, we must remember that the hermaphroditic flowers produce little fruit, as has been shown above.

The influence of environment on floral characteristics of aceituno is also under study; so far there is no reason to believe that elevation exerts any influence in this way. The relatively deeper and richer soils found in certain areas of La Cabaña, Finca Bonaire, Finca Altamira, and Finca Zaprivas give some indication of exercising a certain influence toward a larger percentage of female trees encountered in these plantings, but further study will be required to prove the validity, or otherwise, of this point.

2. Propagation

Grafting. Experiments in the field, using root stocks two to three years old and in nursery beds using root stocks ten to seventeen months of age, have indicated that the best method for grafting of *Simarouba glauca* is the whip or tongue graft (Fig. 15). These grafting methods may be modified somewhat as it has been found that the tongue part is not entirely essential to good grafts. The bark of aceituno shows a tendency to dry out and peel away rapidly from the wood when any wound is made, and the graft must be tied firmly with a suitable band of rubber or polyethylene to insure satisfactory results. The months of June, July, and August give best results for the grafting of aceituno (Fig. 15). However, the time of grafting must also be correlated to the age of the root stock before we can be sure that seasonal variation is the only decisive factor to be considered. Budding is unsatisfactory. It has been noted that budded trees have obtained a growth of six inches at the end of three months after budding, while those which have been grafted at the same time have formed a complete crown of three to four branches, 18 inches in length, within the same period.

Cuttings. Rooted cuttings have proved to be entirely unsatisfactory for aceituno; and although callus formation was found in some cases, no actual rooting took place in any of the experiments shown in the table below.

More recently "cuttings" of fence post size (4″ to 6″ Dia. and 8′ long) have been inserted at monthly intervals. This type of cutting proves very successful in the tropics with such subjects as *Gliricidia sepium* (Jacq.) Steud. and *Erythrina spp.*, but results with aceituno under this method are not yet at hand though some degree of success has been reported by the Centro Nacional de Agronomía. The method would, in any case, be much too wasteful

Type of Cutting	*Quantity*	*Treatment*
Mature Wood 1″—2″ Dia.	50	Placed Obliquely
" " 2″—3″ Dia.	50	Placed Vertically
Semi-mature Wood ½″ Dia.	100	Placed Obliquely
" " " ½″ Dia.	100	Placed Obliquely & Hormodin No. 2#
" " " ½″ Dia.	100	" Vertically
" " " ½″ Dia.	100	" Vertically & Hormodin No. 2#
## Young Growth, Leaves Attached ⅝″ Dia.	100	" Obliquely
## " " " " ⅝″ "	100	" Obliquely & Hormodin No. 1#
## " " " " ⅝″ "	100	" Vertically
## " " " " ⅝″ "	100	" Vertically & Hormodin No. 1#

\# Hormodin No. 1 = 0.1% Indolebutyric Acid.
\# Hormodin No. 2 = 0.3% " "

Under conditions of controlled humidity in propagating case.

of selected material for large scale plantings.

Air layering. Recent results have shown that this may prove successful although final figures are not available, and it is believed that the cost involved would prove prohibitive on anything but an experimental scale.

Apart from the information thus far obtained concerning the most favorable method of vegetative propagation to be adopted, the most significant advance in this respect has been the flowering and fruiting of the first grafts which were made during the years 1953-54. This clonal material taken from a high-yielding tree identified as "El Brannon" is of the white variety, bearing female flowers only. The characteristics of this parent material have now been confirmed in the behavior of some 18 grafted plants at Finca Bonaire. Added to this we have the precocity of bearing obtained by the grafting method. For example, one tree (B-1) yielded a crop of eight lbs. of ripe fruits 16 months from the date of grafting while the average yield of three trees at 18 months from grafting was 4.7 lbs. and one year later the average per tree was 22.8 lbs. of fruit#. The only characteristic which has not remained completely true to form, as compared with the parent material, would appear to be the percentage of oil in the kernels. In the case of the grafted trees we find an average oil yield (dry weight) of 70.63% as opposed to 67.30% in the parent, representing an increase of 3.33%.

Such production compares favorably with a seedling tree of 12 years old.

FIG. 14. Clonal garden of selected, high yielding, scion material of aceituno (Brannon—white variety).

This may be attributed to better soil conditions which have induced vigorous growth in the young trees, but the analysis of oil yield figures of several years must be studied before we can conclude that this is the only reason for such behavior.

3. Adaptation Studies

Control plots for biometric study are not yet available. Variance in factors of age and spacing of the older established plantings, where it is now necessary to remove the majority of the male trees, renders these plots unsuitable for this work. Studies of native stands in various parts of the country have shown certain regions to have a predominance of aceituno among the second growth vegetation.

Even the most conservative interpretation of the published data available (17) would indicate that there are at least 1,500,000 acres of land in El Salvador, (28% of the total land resources of the country), which can be considered marginal from an agricultural viewpoint although, due to population pressures, some type of subsistence agriculture is being carried out in part of this area. Since it has already been proved that aceituno will flourish under the conditions to be found in much of this area, there seems no doubt that, once adapted to commercial cultivation and exploitation as a vegetable oil crop, its impact on the agricultural economy of these areas would be considerable.

It is of interest to note that trees of aceituno have been found at elevations up to 5,000 feet in Central America, but in these cases there is always ample evidence that the plantings have been man-made; i.e,. trees found in parks, gardens, driveways, etc., while trees in native stands are rarely, if ever, found at elevations exceeding 3,500 feet.

4. Selection of High Yielding Trees

Since the first commercial plantings of aceituno were established in 1948, there has been continued interest in the location and selection of native trees which appear to be particularly high yielding from a fruit production point of view. These have usually been fully developed adult trees, of 25 years or more, with well developed crowns, growing in areas particularly favorable to the species. However, since a prerequisite of any selection must be the procurement of accurate production figures for each tree over a number of years, the majority of these trees had to be ruled out because this could not be accomplished for one or more of the following reasons:

1. Inaccessibility, rendering impossible the proper supervision of a controlled harvest.
2. Trees growing on private lands, where the necessary cooperation of the owner could not be obtained to secure the required data.
3. Trees growing on common lands, where people, particularly children, have ready access to the fruit.

For the past three years, however, it has been possible to obtain accurate production figures on three adult trees and the best of these (Arbol Brannon and Luison Negro) have been selected as a source of vegetative propagation material. It is now proposed to form clonal gardens with material from all three trees, at various points, to enable vegetative propagation to be carried out on a larger scale (Fig. 14). Apart from this work of selection among wild trees, yield records have also been kept on 111 trees in random blocks selected from commercial plantings. In addition to giving interesting data about possible high-yielding selections from these seedling stands, this work has also provided valuable information concerning the probable yield per unit of area for seedling trees of known age (Table VII).

Since the potential oil yield of the kernel is of equal importance in the selection of trees, particularly if we are to consider *Simarouba glauca* mainly in the role of a potential vegetable oil crop, an analysis of oil yield has also been carried out on all selected trees. Table V shows the range

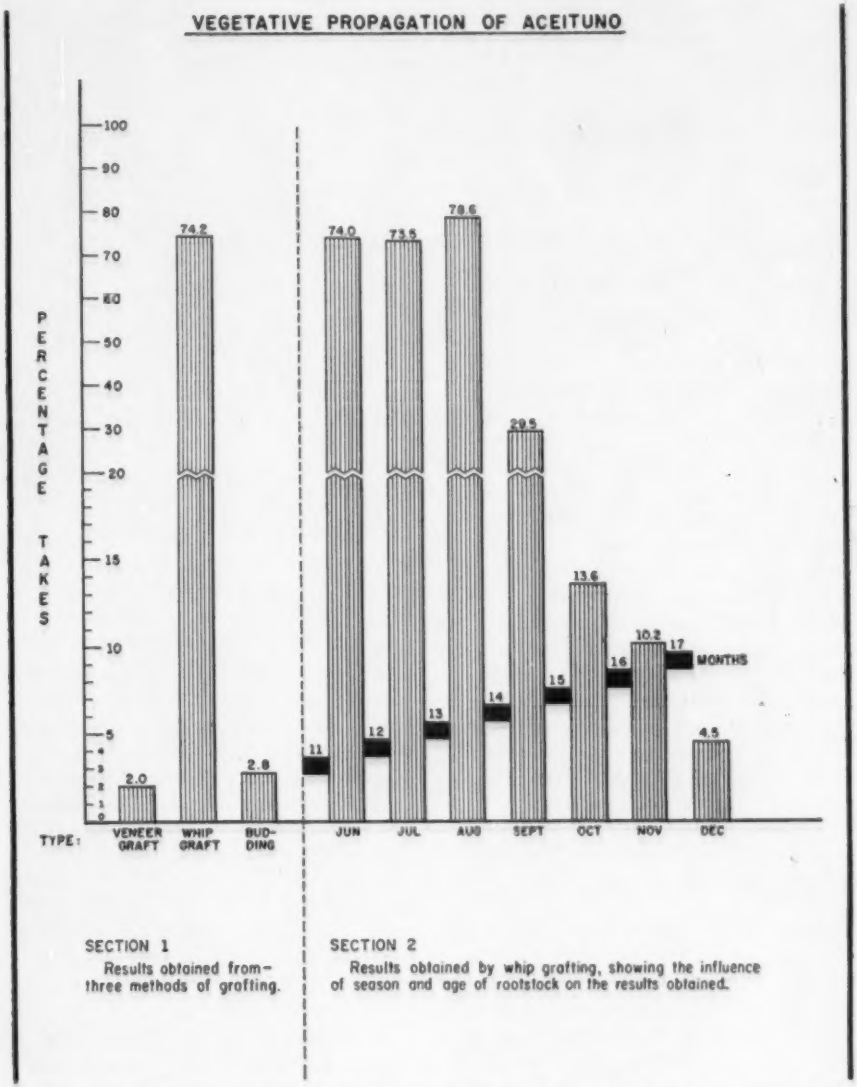

FIG. 15. Vegetative propagation of aceituno, showing best methods and relationship to age of rootstock.

of variation and other pertinent data which has been obtained from these tests. In general, the difference in oil yield figures, between white and black varieties, cannot be considered significant. Figures 10, 11, and 12 show the differences to be encountered in fruit production from andromonoecious, unselected pistillate, and selected pistillate trees respectively.

The desired standards which have been listed as a guide to the selection of high-yielding trees are given in Table VIII.

5. Insect Pests and Diseases

It must be emphasized that the cultivation of aceituno on a commercial scale would probably not support major expenditures for pest control, when based on the values of the products obtained as we now know them, and particularly when the trees become large. Fortunately, we have not encountered any serious insect pests or diseases which actually destroy trees on an alarming scale. It is also encouraging to note that where the wild trees occur in almost pure stands there would appear to be no serious increase in insect pests and diseases in such areas. This indicates that the cultivation of aceituno in pure stands on a commercial scale may be accomplished without insect pests and diseases, common to the species, reaching plague proportions which would necessitate large scale control measures.

By far the most common insect pest is the larva of the thread worm (*Atteva ergartica Walshm.*) which feeds on the growth tips and particularly among the panicles of male flowers where they weave intricate webs. The webs are a significant feature of the male trees during the flowering season. It has been found that these insects can be readily controlled using a 5% DDT spray or Toxaphene at 20%. A comparison of controlled and non-controlled plots during the past year has shown that it is doubtful if control measures are warranted after the plants have passed the nursery stage.

Several species of scale insects have been found to attack the young growth of aceituno and the most common of these, *Toumeyella sp.*, has been controlled by using a mixture of 50% Malathion at the rate of 1% in water. Other scale insects noted on aceituno have been *Chianaspis sp.*, and *Ceroplastes sp.* In addition to the insect pests noted above the only other outbreak of importance has been that of mites (*Brevipalpus phoenicus* Geijskes) which has apparently induced proliferation of the apical buds, causing a "witch's broom" effect on the terminal shoots. This seriously reduces fruiting, and control measures using the more common miticides have not yet proved effective. Also, the action of the mites present is not fully understood, and it has yet to be proved that the distortion of the growth tips is actually being caused by their presence. The following bees are known to act as pollinators for the flowers of aceituno:

Trigona fr. fulviventris Guer.
T. *postica luteipennis* Fr.
T. *ruficrus corvina* Ckll.
T. *testacea orizabaensis* Schw.

The writer wishes to acknowledge the valuable help of Mr. Paul H. Berry (U.S.O.M.), Entomologist of Servicio Cooperativo Agrícola Salvadoreño-Americano, for the identification of the abovementioned insects and for his recommendations concerning control measures of those which are pests of aceituno.

Fungus diseases have not been serious and those which have been encountered are merely of a secondary nature following primary wounds caused by insect or mechanical damage. Examples of this are to be found in the presence of the sooty mold (*Capnodium sp.*) which forms on the "honey" deposited by scale insects and aphids. Another fungus disease, as yet unidentified, has been found in the wounds caused by broken branches or pruning where these have not been adequately sealed with a protective agent.

6. Studies of the Toxic Element Found in the Press Cake of Aceituno Kernels

As has already been stated the kernels of *Simarouba glauca* yield approximately 62% oil when this is extracted on a commercial basis. The resultant press cake is high in protein (60% to 65%), but the presence of a toxic element in the press cake has thus far rendered it unsuitable for anything other than an organic manure.

With a view to greater utilization of the protein to be found in the aceituno press cake, i.e., in livestock feed concentrates, the firm of H. de Sola e Hijos, in collaboration with Dr. Merriam Jones, then (1952) head of the Chemistry Department of the Instituto Agropecuario Nacional, La Aurora, Guatemala, instigated a series of investigations to establish the identity of the toxic element and, at the same time, devise means whereby it might be removed from the press cake. These investigations showed the empirical formula of the toxic element to be $C_{21} H_{34} O_9$. Several research workers (8, 9, 18, 27) have evaluated Simaroubidin, isolated from the bark of *Simarouba Amara Aubl.*, to determine its efficacy and toxicity in experimental chemotheraphy of *Endamoeba histolytica* infections. Private investigations carried on by Merck and Co., Inc., Rahway, New Jersey, have shown that the toxic element extracted from the press cake of *S. glauca* kernels has possible medicinal uses as an amoebicide. The element used as an amoebicide is described (10) as a crystalline glycoside and is referred to under the name of Glaucarubin. This product, under the trade name of "Glaumeba", is now being introduced in most of the major tropical areas.

At the time of writing no practical industrial means has been developed for the detoxification of aceituno press cake. This factor continues to limit the uses to which this by-product can be put. There seems no doubt that the press cake, once adapted to industrial production, will have a decisive influence on the future of aceituno cultivation in El Salvador.

Conclusion

The present investigation, as yet incomplete, indicates that aceituno may prove to be adaptable as a vegetable oil crop, utilizing areas of El Salvador at present considered marginal for farming. While it is true that there is, at present, no shortage of vegetable oil in El Salvador, this depends on continued, large-scale cotton cultivation in the country. The permanency of the cotton industry in El Salvador and in the other Central American republics depends in large measure on the present structure of world cotton prices. Any radical lowering of these prices would immediately alter the outlook for cotton cultivation in El Salvador and create a local demand for vegetable oil which could, in part, be supplied by aceituno. Additional benefits to be derived from aceituno cultivation are as follows:

Soil and watershed conservation, source of lumber suitable for local crafts and the match making industry, the protein content of the press cake as cattle feed or fertilizer, and the medicinal by-products referred to in this report.

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Utilization Abstract

Cactus apples. The fruit of several Opuntia species has been used for centuries in the old and the new world. The fruits have a fine flavor reminiscent of apples, or pineapples, or to some, cooked apples. Near Lakeside, California, a 40 acre farm specializes in this fruit, shipping 20-25 carloads of cactus apples to northern and eastern markets. The plants thrive in the semi-arid regions of southern Calif. Planted in long rows on 20 ft. centers, the plants are vegetatively propagated from young "pads" of the succulent stem sections of the *Opuntia* species. In 4-5 years the plants bear and are good for about 20 years of production. They are prolific growers and bearers.

The fruits, which may be either eaten fresh or prepared as a jelly, require ginger handling, for the spines on the surface are dangerous. At present a mechanical brusher is used to scrub off the spines before packaging and shipping. The fruits are known as either "tuna" by some, or "el nopal" by others. They may be pealed and eaten, the large seeds going down easily—the seeds and fruit are said to aid digestion.

The young fleshy green pads—stems—may be used as a boiled or fried vegetable, tasting like either okra when boiled or the flavor modified by frying and used as a tortilla with sprinkled cheese and chili sauce. The stems also contain a heavy muscilage, and the juice from them is or was used as a dye. Gordon L'Allemand. *Cactus and Succulent Journ.* **30**(*4*): *110-113. 1958.*

Critique on Apomixis in Sugarcane

SAM PRICE [1]

Introduction

Apomixis, particularly that part of apomixis called parthenogenesis, is mentioned with increasing frequency in sugarcane literature; and at least two general works list *Saccharum* as a genus in which apomixis plays a part (2, 8). However, the evidence upon which these reports are based is scanty and indecisive. A critical review of the subject is overdue.

Apomixis defined

Apomixis is a general term applied to all types of asexual reproduction which replace or substitute for the sexual process. "Vegetative apomixis" is reproduction by specialized propagules which replace the flowers in the inflorescence. (In its broadest interpretation this term includes instances in which sexual processes are suppressed and reproduction is carried on by normal vegetative structures such as rhizomes and stolons.) The phenomenon should be easily recognized where vegetative apomixis predominates, but there may be great difficulty in recognizing the more subtle forms of apomixis collectively termed "agamospermy". In "agamospermy" reproduction is by means of true seeds, but the sexual process is circumvented in a variety of ways. One way, called "adventitious embryony", is for cells of the integument or the nucellus to produce embryos directly by somatic cell divisions. Other forms of agamospermy are collected under the term "gametophytic apomixis". This term embraces a variety of processes by which diploid gametophytes are produced, and in which egg cells or other cells develop into embryos without benefit of fertilization. Development of an embryo from an unfertilized egg is that part of apomixis properly designated as "parthenogenesis". In many plants in which apomixis is recurrent in the life cycle, generation after generation, a balance is achieved between two alterations of the normal reproductive processes. In balanced recurrent apomixis the mechanisms which circumvent or compensate for the meiotic reduction of chromosome numbers are accompanied by a capability of the diploid cells thus produced to develop without fertilization. Plants are also known in which such a balance is not achieved. The production of diploid sex cells followed by fertilization results in progeny with increased chromosome numbers. Meiotic reduction followed by parthenogenesis results in progeny with reduced chromosome numbers. In many plants where normal sexual reproduction usually predominates, parthenogenesis occasionally follows the development of a haploid embryo sac, and a haploid individual results.

The replacement of flowers by propagules is not known in *Saccharum*, and, unless one wishes to accept the very broadest definition of the term, vegetative apomixis may be excluded from further consideration. Certain forms of agamospermy have been reported in sugarcane; it is appropriate, therefore, to comment here upon the genetic result that may be expected. In adventitious embryony and some of the types of gametophytic apomixis, embryos result from a series of somatic cell divisions

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which exactly reproduce the maternal genotype. Should apomictic sugarcane seedlings be derived from these processes, they would resemble their maternal parents as closely as one stool of a vegetatively propagated cane variety resembles another. Exact maternal resemblance, supported perhaps by embryological observations, would provide the evidence necessary to establish the occurrence of such phenomena. However, other forms of gametophytic apomixis may include modifications of the meiotic process, and some of the modifications, particularly those said to occur in the sugarcanes, would lead to genetically variable apomictic seedlings. Exact maternal resemblance would not be expected here, and other evidences for apomixis would be required.

Control of pollination

Evidence for the occurrence of apomictic but genetically variable seedlings would be provided by the production of seedlings under conditions which absolutely exclude all possibilities of contamination and self- or cross-pollination. Under the actual conditions of cane breeding the possibility of contamination in pollination and in the handling of seed and seedlings is not really remote. Such sources of error cannot be entirely ignored in dealing with seedlings obtained by procedures commonly employed in sugarcane breeding programs, but they are controllable. Of greater concern is the matter of excluding the possibilities of self-pollination. Because the florets of the sugarcane are extremely small and the inflorescences are very large, manual emasculation would be extremely difficult and unreliable. Special techniques such as hot-water emasculation might conceivably be developed to a point of practical usefulness but could not be depended upon for critical experimentation. Self-incompatability in varying degrees is probably present in the breeding canes but may not completely exclude the possibility of selfing. Sugarcane breeders utilize self-incompatability, but more often they rely upon male-sterility in choosing clones to be used as females. It should be pointed out, however, that male-sterility in the sugarcanes almost always depends on the failure of anthers to dehisce and that, where pollen in the indehiscent anthers of male-sterile clones has been studied, at least a small percentage of presumably viable pollen has usually been found. Furthermore, clones described as male-sterile under one set of conditions often produce dehiscent anthers under different circumstances—late in the flowering seasons, in other years, or at other locations, for example. In South Africa and Louisiana, where breeders have had great difficulty in obtaining pollen from any sugarcane variety, sufficient pollen is now produced under controlled greenhouse conditions to carry on rather extensive breeding programs. Since the environment is demonstrated to have such a marked effect upon pollen production and dehiscence, it would seem perilous to deny the possibility of selfing and to accept as apomictic derivatives those few seedlings which may be obtained when "male-sterile" clones are bagged or isolated, or when seedlings which resemble but do not exactly duplicate the female parent are obtained from interspecific or intergeneric pollinations.

Chromosome numbers and their transmission

Selfing is probably the most difficult source of error to control, and distinguishing between suspected apomictic and selfed seedlings becomes the central problem in establishing the occurrence of apomictic processes. Since relationships between chromosome numbers in parents and seedlings have been cited as evidence for apomixis in sugarcanes, it is appropriate for us to consider chromosome transmission as it would be expected in sexual and apomictic reproduction in the canes.

A peculiarity in the sugarcanes is the sexual transmission of somatic chromosome numbers by female clones in certain crosses (10). There is little likelihood that an individual whose somatic chromosome number equals the sum of the maternal somatic and the paternal gametic number would be suspected as resulting from apomixis, and we need give no further consideration to such individuals. However, explanations for female transmission of somatic chromosome numbers have a direct bearing on the subject at hand. In sugarcane, egg cells with somatic chromosome numbers result from fusion of daughter nuclei after the second meiotic division in the innermost megaspore dyad according to Narayanaswami (7). However, according to Bremer (1), postmeiotic endomitosis in the innermost megaspore is responsible for doubling the chromosomes. The phenomena described by these authors have been invoked by others to explain the occurrence of diploid eggs which are said to develop parthenogenetically to produce apomictic seedlings.

It will be instructive to examine chromosome transmission in sugarcane as it would be expected in selfing, in apomictic processes which are essentially series of so-

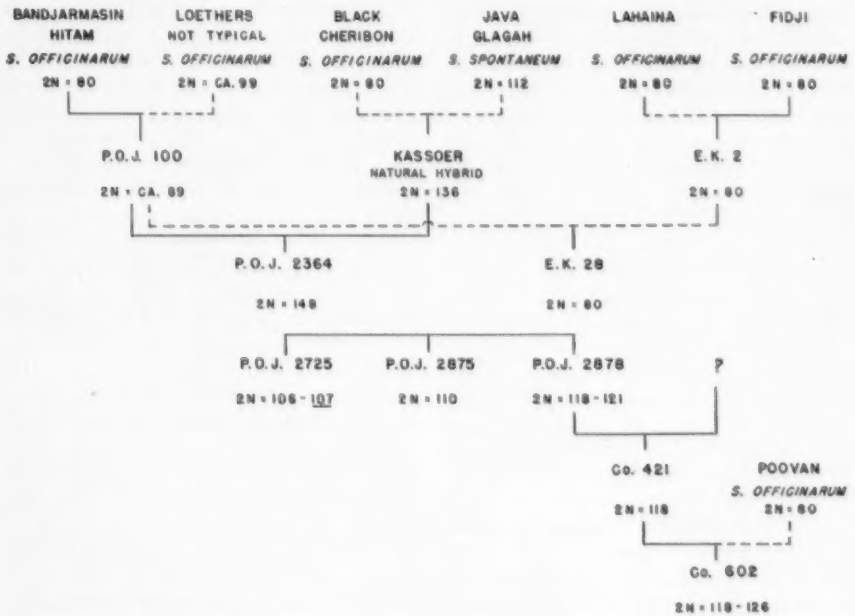

Figure 1. Pedigree including varieties mentioned as producing apomictic seedlings. Broken lines indicate at least an element of uncertainty. Co. 421 was obtained when P.O.J. 2878 was pollinated by the 80-chromosome *Saccharum officinarum* variety B. 3412. However, on the basis of the morphology and chromosome number of Co. 421, *S. officinarum* has been rejected as a possible parent. Stevenson (13) suggested that Co. 421 is a selfed seedling, while Dutt and Rao (3) thought the male parent to be Co. 285 ($2n = 112$). Co. 285, in turn, is of doubtful parentage but has been suggested to be a *S. officinarum* × *S. spontaneum* F_1 hybrid. Co. 602 was obtained when Co. 421 was pollinated by Poovan, an 80-chromosome variety of *S. officinarum*, but it may be a selfed seedling. (see text.) The chromosome numbers shown here are taken from the literature, and, except for Lahaina, have not been verified by the writer.

matic divisions, and in parthenogenetic development of egg cells whose chromosome numbers are doubled by the processes described by Narayanaswami and by Bremer. Thus we can evaluate the use of chromosome numbers in assessing individuals as apomictic or non-apomictic derivatives.

Selfing in forms such as the 80-chromosome noble canes, which are heterozygous and in which the meiotic divisions are generally regular, is expected to produce a morphologically variable progeny in which the chromosome numbers are the same as the parental chromosome number. Most of the modern breeding canes, including most of those in which parthenogenesis is reported, are hybrid derivatives (Fig 1) with a great deal of cytogenetic complexity. When meiosis is studied in such canes, it is found to be characterized by varying numbers of unpaired and lagging chromosomes. Because of these meiotic irregularities, such canes cannot be expected to contribute exactly half their chromosomes consistently to their megaspores, to their microspores, or to their sexual progeny. Seedlings from selfed plants have varying numbers of chromosomes, usually fewer but sometimes more than the parental clones (13). Such cytologically variable seedlings are, of course, morphologically variable also.

It has been mentioned above that apomictic processes which proceed entirely through somatic cell divisions duplicate the maternal genotype; they also duplicate the karyotype. Chromosome numbers would provide supplementary evidence for apomixis if meiotically irregular forms produce seedlings which duplicate the parent cytologically and morphologically. Chromosome numbers would be a valueless supplement to morphological observations if the parental form exhibits regular meiotic divisions.

Now let us examine the expectancies if apomixis results from parthenogenetic development of eggs whose chromosome numbers have doubled by endomitosis after meiosis. In forms with regular meiotic divisions this mechanism would produce apomictic seedlings whose chromosome numbers equal the parental number, and in this respect apomictic seedlings would not differ from selfed seedlings. There would be a difference, however. The first generation of selfing, on the average, should increase homozygosis by 50 percent over that of the parent. On the other hand, all the seedlings produced by the apomictic process assumed here would be completely homozygous at all loci. Perhaps progeny tests could distinguish the two possibilities. The occurrence of this same apomictic process in forms with irregular meiotic divisions would also produce results superficially similar to selfing. It has been repeatedly stated in the literature that postmeiotic chromosome doubling and parthenogenesis would lead to genetically and therefore morphologically variable individuals. It has not been mentioned that the very meiotic divisions which produce genetic segregation would, in forms with irregular meiosis, also lead to cytologically variable progeny. Thus, chromosome counts would appear to have little value in distinguishing selfing from apomixis by the process mentioned here. However, here, too, there would be a difference. Selfed seedlings presumably could have any chromosome number within a limited range and on the average would be 50 percent more homozygous than the parent. An apomictic process in which endomitotic chromosome doubling occurs after meiosis should produce individuals with even chromosome numbers only, and these individuals should be completely homozygous.

If parthenogenesis were to follow second division restitution or an equivalent process, one could expect no differences between chromosome numbers in seedlings obtained thereby and in seedlings obtained by selfing. In either case seedlings from a parent with undisturbed meiosis would

have the same chromosome number as the parent. A parent with irregular meiosis would produce seedlings with variable chromosome numbers by either process. Odd and even chromosome numbers would occur in both types of seedlings if unpaired chromosomes divide in the first meiotic division. Seedlings resulting from parthenogenesis following second division restitution, whether from parents with regular or irregular meiosis, would be homozygous in the proximal segments of all their chromosomes. Heterozygosity in distal segments of their chromosomes would depend upon the frequency and location of crossing over in the first division. Homozygosity in such seedlings would exceed that of their parent by something more than 50 percent.

Literature Review

Embryological studies in *Saccharum* are rare. Dutt and Subba Rao (4) "observed in two sections that a few divisions had taken place in the egg but that the characteristic coenocytic stage of the endosperm was absent." They interpreted the condition of the endosperm to mean that pollination had not taken place and therefore that the embryos were developing parthenogenetically. They called this ovogenic apogamy. In one ovule they also noticed that two embryos were developing in an embryo sac. The second embryo was said to have developed by fertilization of one of the synergids by the second male nucleus, and it was therefore not interpreted as apogamous. Narayanaswami (7) found a several-celled embryo in "an unpollinated ovule of *S. officinarum*" while the "two polar nuclei were still unfused and showed signs of disintegration." In another ovule a developing embryo was interpreted as arising through nucellar embryony. Narayanaswami also observed "secondary egg cells" in embryo sacs. (Although this latter observation and the twin embryos noticed by Dutt and Subba Rao might have been expected to lead to twin seedlings, no multiple seedlings have yet been recorded in the sugarcane literature. The only unpublished account of twin seedlings in *Saccharum* that the writer knows of is that of twins obtained by Dr. E. W. Brandes from a *S. officinarum* L. × *S. spontaneum* L. hybrid with $2n = 128$, when pollinated by *S. officinarum*. It was thought that one or both of the twins might be haploids; however, the writer found the somatic number in the one twin which survived to be approximately 170. There are still no known haploids in *Saccharum*.) The two papers just cited are the only embryological studies in *Saccharum* which describe phenomena that might give rise to apomictic seedlings by orthodox means. Subramanian's unpublished study (14) has been cited as describing a curious dual spindle formation in the first meiotic metaphase of an embryo sac mother cell division (see below), but this phenomenon has no direct bearing on apomixis. Bremer (1), who studied megasporogenesis through the first few divisions of the embryo in P.O.J. 2875 (see Fig. 1) and in other canes, concluded that diploid egg cells arise through endomitosis following meiosis and that aneuploid and even tetraploid egg cells may be formed occasionally when the endomitotic process occurs at the close of the first meiotic division. Although Bremer's studies were extensive, he found no evidence of parthenogenesis.

Janaki Ammal (5) reported on crossing P.O.J. 2725 (see Fig. 1) with *Imperata cylindrica* (L.) Beauv. ($2n = 20$). As controls, unpollinated inflorescences of P.O.J. 2725 were bagged, and over several years five control seedlings were obtained. Although she found 21 percent viable pollen and dehiscence in 2 percent of the anthers of P.O.J. 2725, Janaki Ammal did not accept selfing as the only explanation for the seedlings. Rather, she supposed that "selfing or parthenogenesis is therefore responsible . . . ." Of 35 plants ob-

tained from the cross with *Imperata*, 14 were studied cytologically. Two of these plants had 106 chromosomes (which, according to Janaki Ammal, is the chromosome number of the female parent, P.O.J. 2725) and were interpreted as having originated through adventitious embryony ("vegetative embryony"). Six plants had chromosome numbers in the range 108 to 112 and were said to have originated sexually or through diploid parthenogenesis. Five seedlings with chromosome numbers of 120 to 134 were called true F_1 hybrids, and one plant with 156 chromosomes was called a triploid self.

In view of the pollen viability and dehiscence reported, it is difficult to understand why the control plants and the plants from the hybridization with 108 to 112 chromosomes were not simply accepted as selfed seedlings. It was said of the 106-chromosome plants that they "are in all probability vegetatively apomictic plants and should be considered as clones of the mother plant." However, in the only characteristics reported for these plants—pollen fertility and percent sucrose—they differ somewhat, though perhaps not significantly, from the maternal clone. Furthermore, most cytologists who have studied P.O.J. 2725 have given 107, not 106, as the somatic chromosome number of that clone. If the correct chromosome number is 107, it is obvious that 106-chromosome plants cannot have originated from P.O.J. 2725 through adventitious embryony.

Janaki Ammal's is the only report in the sugarcane literature of apomictic seedlings that exactly reproduce the maternal genotype. Had the phenomenon occurred with any frequency, it surely would have been noticed by expert sugarcane breeders who could easily recognize reproductions of the important breeding clones.

Parthasarathy (9) reported that Co. 421, a complex (Fig. 1) and "pollen-sterile" clone with $2n = 118$, upon being dusted with the pollen of *Coix* and of bamboo, gave rise to seedlings with 86 and with 118 chromosomes. Both classes of seedlings were inferred to have risen parthenogenetically. Subramanian, as cited by Parthasarathy (9), reported $2n = 126$ in Co. 602, a seedling obtained when Co. 421 was pollinated by the 80-chromosome noble cane, Poovan (Fig. 1): "The expected number in the seedlings should be either $2n = (59 + 40)$ or $2n = (2 \times 59 + 40)$. But actually the number obtained from Co. 602 is $2n = 126$, *i.e.*, $(86 + 40)$, and this is explainable only from the knowledge of the behavior of Co. 421 in giving rise to seedlings with $2n = 86$ by parthenogenesis." Apparently no thought was given to the probability that Co. 421, because of ordinary meiotic irregularities, would contribute chromosome numbers other than 59 or 118 to its sexual offspring. Subramanian studied megasporogenesis in Co. 421, and "during the first division, the 59 bivalents instead of lying on the same plate, arranged themselves in two groups during the metaphase. One of the groups on the equatorial plate consisted of 43 bivalents, and the other lying above toward one of the poles had 16" (9). It is inferred that the chromosomes which form the 16 bivalents are eliminated and the others form cells with 43 chromosomes which somehow become doubled. More recent papers have made use of Bremer's account of endomitosis following meiosis to account for this doubling. The 86-chromosome eggs, supposedly produced, conveniently account for the chromosome number given for Co. 602 ($86 + 40 = 126$) and for the 86-chromosome "parthenogenetic" seedlings. Enthusiasm for this remarkable phenomenon, later entitled "chromosome elimination *en bloc*," has not been repressed by the later report (11) that Co. 602 has 118, not 126, chromosomes. It may be difficult to account for the 86-chromosome seedlings, but selfing supplies a logical explanation for the origin of Co. 602 and other 118-chromosome progeny of Co. 421.

This explanation gains credence from the fact that Co. 421 has been shown to produce variable amounts of viable pollen (6, 15).

Raghavan also cited Subramanian and in a series of papers reported chromosome elimination *en bloc* and parthenogenesis. One of these papers (12) adequately represents the others. Table 1, therein, lists the chromosome numbers and parentages of a number of canes said to have arisen through diploid parthenogenesis. In each case the maternal clone is a complex hybrid. The point was made that doubling of the chromosomes prior to diploid parthenogenesis is a postmeiotic phenomenon and that therefore the parthenogenetic seedlings need not, and indeed do not, resemble their maternal parents exactly. There is no suggestion, however, that meiosis in these complex maternal canes should produce cytologically variable as well as genetically variable offspring. In fact it is stated that "Care has been taken to include in the list only such cases as show different chromosome numbers among the parents. In all of these cases cited, the hybrid Co. canes show only the maternal number irrespective of the chromosome number of the paternal parent." Thus, the sole evidence that the clones are derived parthenogenetically is their chromosome number. The unreliability of such evidence has already been discussed. Selfing, or in some cases successful crossing, would adequately explain all the offspring listed. The fact that care was taken in selecting the clones to be tabulated explains why each clone has the same chromosome number as its maternal parent.

TABLE 1.

CHROMOSOME NUMBERS IN A SMALL PROGENY FROM H. 53-9070* × SELF.

Clone	2*n* chromosome number
U.S. 56-29-1	123
-2	121
-3	111-112
-4	111
-5	121
-6	119 + 1 or 2 fragments
-7	109
-8	123

*H. 53-9070 is a 136-chromosome ($2n + n$) *Saccharum officinarum* × *S. spontaneum* hybrid from the cross Striped Mexican ($n = 40$) × Glagah-Imp. 1286 ($n = 56$).

Raghavan's Table 2 lists seedlings interpreted as having arisen by parthenogenesis preceded by elimination of chromosomes *en bloc*. Most of the female parents listed are complex hybrids. However, chromosome numbers in the offspring which deviate from the maternal chromosome number or from the number that would be expected if each of the parents were to contribute exactly half their chromosomes were accepted as evidence for elimination *en bloc* and parthenogenesis. Although a few of the seedlings have chromosome numbers low enough to be of particular interest, the chromosome numbers of most would be understandable if hybridization of the parents listed was successful or if the maternal clone was selfed. To invoke chromosome elimination *en bloc* to explain a 112-chromosome seedlings from Kassoer × self is particularly unnecessary. Kassoer is a 136-chromosome natural hybrid from *Saccharum officinarum* × *S. spontantum* (Fig. 1), long known to exhibit irregular meiotic chromosome behavior of the usual sort and to contribute varying numbers of chromosomes to its offspring. The cytological variability that may be expected upon selfing a hybrid comparable to Kassoer is illustrated by the writer's observations presented in Table 1. The small progeny obtained from selfing H. 53-9070, a 136-chromosome *S. officinarum* × *S. spontaneum* hybrid, exhibits a range of chromosome numbers from $2n = 109$ to 123. There is no reason to suppose that any of these seedlings arose through apomixis.

Conclusions

The embryological studies of Dutt and Subba Rao (4) and of Narayanaswami (7) indicate that some forms of apomixis may occur occasionally in *Saccharum*. Nevertheless, if apomixis occurs in sugarcane, it must do so very infrequently, for there has been no progeny or individual seedling which has been adequately demonstrated to be derived from any of the apomictic processes. Acceptance of reported instances of apomixis in the sugarcanes requires an absolute faith in the complete male-sterility of maternal clones. It also requires the assumption that contamination has been avoided. Chromosome elimination *en bloc*, though referred to many times in the literature, is poorly described and illustrated. If it occurs, its importance has probably been overestimated.

Acknowledgments

The writer is indebted to Drs. Walter V. Brown, A. J. Mangelsdorf, and John N. Warner for reading the manuscript and for offering valued suggestions.

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Bluegrass' Grassroots Empire

Probably 90% of Kentucky bluegrass seed harvested for lawns comes from "wild" plants of polyglot origin. Perhaps one virtue of seed from several "wild" sources is that in every seed mixture there are seeds adaptable for most environmental requirements.

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Kentucky bluegrass, mainstay lawn grass over two thirds of modern America, is so widely used in lawns that it comes to be taken for granted. Yet the unique system of growth and harvesting, which will form the substance of this article, may have considerable bearing on its outstanding success as a lawn grass.

Many lawn seeds are produced rather prosaically by agronomic procedures: planting in rows, cultivating, weed control, irrigation, harvesting by combine, etc. Of course, these practices give high quality products efficiently, but it is interesting that Kentucky bluegrass survives as a major seed product without being so coddled. Except for a few tannin leaves; some wild nuts, fruit, and berries; occasional medicinal herbs and native grasses, little in North America today enters commerce from adventive stands. Probably 90% of the bluegrass comes from "wild" plants of polyglot origin.

History

The origins and migrations of Kentucky bluegrass, camp-follower of mankind, are obscure. Certainly Kentucky bluegrass was known in Europe in first recorded history. Eubulus, among the Greeks, had a word for it. When Linnaeus named it *Poa pratensis*, "Poa of the meadow", it was widely spread through all of northern Europe and much taken for granted in England.

Records from the early English colonies give no botanical descriptions, although not long after Jamestown "English grass" was prevalent from Virginia northward along the Atlantic Coast. This is significant, since New World species invariably merited the prefix "Indian" (as Indian corn, for maize). English grass, as termed by later colonists, referred to familiar sward species of the homeland, more particularly to a mixture of Kentucky bluegrass and white clover, natural companions in invasion of the white man's fields. It is said that the American Indians referred to Kentucky bluegrass and certain Old World weeds as arising "in the footsteps of the white man".

The first accurate botanical delineation of bluegrass in the New World was by Per Kalm in 1749. He reported bluegrass widely spread through the St. Lawrence Valley and French Canada. French missionaries had been to the Illinois country as early as 1672, with missions at Vincennes and Kaskaskia before 1700. The French worked intimately with the Indians and are known to have distributed garden seeds. It is not unlikely that Kentucky bluegrass descended via a Great Lakes route to southern Illinois, Indiana, and perhaps Ohio. Birkbeck, in "Letters from Illinois" 1818, reports "—where—caravans—encamped—and given their cattle hay made of these perennial grasses, there remains ever after a spot of green turf—conclusive against the prevailing

notion that the natural grasses—are best adapted to every soil and climate".

Whether white man carried bluegrass to central Kentucky from the Wabash and Ohio Valleys or whether it worked its way there before colonization can only be guessed. Certainly bluegrass seems to have beaten Boone to central Kentucky. Whether Indiana or Ohio was the original source of the seed for Kentucky has been argued vigorously; some say it was carried back by the Kentucky volunteers from the Wabash Valley after Harrison's Tippecanoe Campaign. Others maintain that seed came from the Pickaway plains of southern Ohio as soldiers with Mad Anthony Wayne returned homeward to Kentucky.

On rich phosphate soils around Lexington it found conditions so to its liking that it nourished the first cultural center west of the mountains. As colonization moved westward from Kentucky, Kentucky bluegrass came along with the white man wherever he turned prairie soils or cleared forest.

Soon bluegrass was in Missouri and Iowa, mainstay production centers today. It is still colonizing westward. Areas in Wyoming and Montana, which previously never produced a crop, have been sending adventive bluegrass seed to market recently. During World War II sections of Minnesota were encouraged to plant flax, plowing down prairie. When subsidization ended and the flax lands were abandoned, bluegrass for the first time moved in, and fine seed crops came from parts of Minnesota where a decade before they were unknown.

Production

Production varies widely from year to year but averages approximately 20 million pounds, mostly for lawn purposes. In addition to seed, bluegrass sod supports an undeterminable quota of livestock while holding soils more proficiently than might a lesser grass (hay bunchgrasses).

As progressive producers have shown, it is possible to harvest 200 pounds of bluegrass seed from an acre of Kentucky sod in a good year. With fertilization and insect and weed treatment even more seed would be possible, although this is about the limit most harvesting equipment can handle. In years of high seed prices a good income can be obtained from seed alone, and even in average years a substantial income can be realized. Moreover, a blooded Hereford per acre can gain a pound per day on land having to be withdrawn from grazing only for about six weeks through May and June. So, bluegrass lawn seed production becomes an integrated part of land management.

Production in Kentucky centers in a few counties around Lexington. Normal rainfall in Kentucky is double that in the Dakotas. Although bluegrass flourishes on the high phosphate soils of north central Kentucky, these are heavily leached and long used. Seed yields might well be less, except that in central Kentucky bluegrass farmers have begun to fertilize the grass and treat against weeds and insects on a scale not yet permissible on the less costly lands of the West.

Kentucky averages less "clean out" than the West—that is, a lower percentage of good full seed being obtained in the cleaning of the rough, cured seed from the curing yard. The difference on occasion may be as much as 25%, comparing, for example, Minnesota with Kentucky. Such comparison is not exactly fair, in that, as we shall see, the harvesting ("stripping") operations are not identical. The machinery and methods used in Kentucky perhaps bring more trash, chaff, and immature seed to the curing yard, because the ripening seed is "combed" from the inflorescences in Kentucky rather than flailed out as in the West.

Methods of production in the western district reflect the tremendous distances and tremendous acreages. "Lying in wait" for a crop and moving harvesting

machinery perhaps across several states to gather seed from inexpensive "natural" stands, favored that year with good yields, has proved a better risk than to capitalize and intensively manage given fields where the crop may or may not be good because of rainfall variation. In the West, quantity of acreage substitutes for high acre yields; 25 pounds is worth harvesting, if enough acres all together can be conveniently stripped by equipment on the scene. The land and the charge for stripping rights can easily become secondary to expense of equipment, manpower, and transportation.

Here, too, seed production may be subsidized by use of the same land for hay or grazing in other seasons. Missouri and eastern Kansas mark the southern limit of bluegrass seed production in the West. Conditions are somewhat similar to those of Kentucky. Land values have risen, and turfgrass must be pastured. Bluegrass sods of northern Missouri and Iowa, the chief producing region of the lower West, are almost invariably grazed except for those few spring weeks leading to the June seed crop. In drought years, when grass is scarce, cattle may not even be removed from the pastures to permit good development of seedheads (inflorescences.)

In the northwest agriculture is still not this intensive. In considerable acreages in South Dakota (usually the leading northern state), North Dakota, and Minnesota a hay crop is allowed to grow rather than be pastured. As we shall see, a single cutting for hay on the northern lands produces sod of different appearance than on the continuously grazed lands of the southern zone. That this seems to have little influence on the genotype of the grass will also be shown.

Much of this northern land is unfenced, and whole sections can be harvested without tedious manipulations of strippers. The land is generally new and fertile, the seedheads big, the seeds full and heavy under this system of meadowing rather than grazing.

When rainfall is right in this area, a real crop can be made relatively inexpensively. Clean out from cured seed as high as 60% is not too uncommon, compared to a more usual 30% to 40% in Kentucky and Missouri.

Of course, Kentucky bluegrass did not stop at the border. Fine sweeps of bluegrass extend up into Canada to Hudson Bay and beyond. Boggy spring roads, transportation, and harvesting difficulties, rather than grass stands, limit Canadian production. Nevertheless, appreciable harvests occur especially around Lake Manitoba.

If this, then, is the general disposition of Kentucky bluegrass, yielding the seed that becomes fine lawns, speculation may be warranted on what influence such wild, adventive existence may have. Even without that background it is evident that grass existing today in the luscious Inner Bluegrass of Kentucky, the productive pastures of Missouri and Iowa, and the wilder hay lands of the Dakotas and Canada has attained harmony with environment essentially unaided by man. If natural selection can be operative in the short span of agriculture on this continent, certainly the "misfits" in *Poa pratensis* could have dropped by the wayside. Perhaps this is one of a fortuitous set of circumstances making Kentucky bluegrass a fine pasture grass and also premier lawngrass.

Botany

Hitchcock lists 49 species of *Poa* for the United States. Relatively few of these, however, occur in the northeast in the path of early migration; but whatever the classification (Europeans split our *P. pratensis* into several species), certainly the genetics must be complex. Apomixis limits sexuality in Kentucky bluegrass; but in spite of this, variability is tremend-

ous. Selections from any pasture or lawn, space planted, can give an almost unbelievable range of sizes, shapes, and measures of vigor.

We have examined Kentucky bluegrass (Fig. 1) over most of its present seed production range. Certainly northern sod appears grossly different from southern.

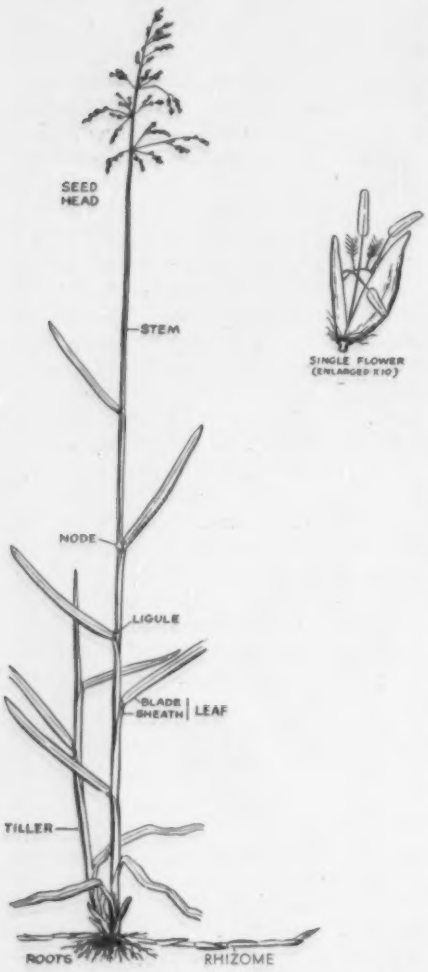

Fig. 1. Diagram of the parts of Kentucky bluegrass (*Poa pratensis*) reduced.

Northern clones tend to be clumped, separated, with narrower, often in-rolled leaves, the basal culms rigid and siliceous. Shoots per square foot may be only half that of the southern pastures. Inflorescences are often larger and heavier.

Much of this is superficially caused. The meadowing of the north does not encourage the tillering that does the constant grazing of the south; leaves become longer, but fewer, just as would unmowed lawn compared to mowed. The limited prairie rainfall seems instrumental in keeping plants widely spaced, tough, and seemingly siliceous. This is especially apparent on sandy soils around ancient Lake Agassiz in eastern North Dakota and western Minnesota. Yet, take sods from the north and south to a common environment, and shortly no difference can be noted between them—that is, no readily apparent difference.

However, grown side by side, northern bluegrass "on the average" is phenotypically somewhat different from southern. Scatter diagrams show northern populations to have generally longer leaves, with less range in width. Greatest eccentricity is in Kentucky; there the widest variability can be found.

However, we cannot emphasize too strongly that this diversity is extremely plastic. Sods from the four corners of the bluegrass map moved side by side gradually mold to a sameness for the new surroundings. They flower for the new location even if parent sod be weeks ahead or later. Few crops exhibit such plasticity and adaptiveness. It is not like alfalfa, soybeans, and corn, where a hundred or so miles difference in latitude or changing rainfall zones can make much difference.

Bluegrass genetics, confused perhaps by facultative apomixis, cannot yet, as far as I am aware, point out linkages and mutable characteristics. The extensive selection work in Wisconsin has shown lack of persistence in characters, comparing one circumstance with another or one year with

a subsequent. Bluegrass clones seem to merge readily into the species complex, even when highly distinctive and self-perpetuating (through apomixis) as spaced plantings. One would presume that the greatest range of variation is found in Kentucky and that any populations from usual seed sources would exhibit great variability.

If there be this variation in every population, certainly present harvesting and marketing methods perpetuate this potential diversity. Perhaps a hidden virtue in bluegrass from "wild" sources is that there is a candidate in the seed mixture for every likely environmental niche. Whether in sun or in shade, on high ground or low, clipped or left unmowed, fertilized or not fed, on north slope or south, the makings of a good lawn are there!

Prediction of Crop

To a degree it has been possible to prognosticate seed crop on the basis of the previous year's weather. At least in Missouri, Iowa, and Kentucky, contrary to what might be expected, droughty summers are beneficial (presumably conserving soil fertility against leaching, and plant reserves through dormancy). Good autumn rainfall is needed; so is sufficient rainfall in spring, necessary in order that the by-then-determined inflorescences do not deteriorate. Indications were for a bumper bluegrass seed crop for South Dakota in 1955. Harvest was a failure, and almost no acreage was stripped; yet inspection of this blank upon the production map showed many shriveled seedheads only a few inches tall. Drought in May had undermined at the last minute a potential mountain of seed.

About Christmas an induction takes place on the growing point of the more robust bluegrass culms. Some evidence indicates that there can also be late spring induction, although previously it was presumed that a winter combination of events alone was determining (low temperatures, though not necessarily freezing; short day length; and adequate green leaf). Our findings show that autumn conditions are basic. For seed production, the quantitative induction during winter is of extreme importance. Unless at least some 80 inflorescences per square foot are "triggered", chances are that the stand will not be worth harvesting.

Good sod management can implement seed production. Mention has already been made of Kentucky's new proclivity for helping the harvest. Weeding, feeding, and insect spraying are accepted practices. Experience has shown that fertilization in early autumn encourages tillering, producing more inflorescences than can be effectively supported by the sod. Seed heads are numerous but small, neither high-yielding nor effectively harvested. On the other hand, late spring feeding encourages tall, spindly grass, perhaps turning too much to leaf and being prone to lodge. Ordinarily fertilization in late February or early March strikes the best intermediate balance. There is still question as to whether fertilizer should be complete, or if 50 lb/A of nitrogen alone is sufficient (central Kentucky soils test high for phosphate). Excellent booklets on the management of bluegrass for seed have been put out through the University of Kentucky. In the western district there is a little insecticidal spraying to control "white top" (apparently a fungus trouble spread by an insect). Limited areas may also be sprayed for weeds. Sod is seldom fertilized.

Harvesting

Western producers watch and wait through May, contracting for acreage on the basis of their experience and judgment, for harvest in early June in southern locations and well into July in northern areas. Choice locations are sought out hundreds of miles distant. These are hectic dawn until midnight days

Fig. 2. McCormick style strippers harvesting seed near Winchester, Kentucky.

for the advance guard in the rough-and-tumble lining up of acreage. Contracts with local residents or owners and arrangements for tractors or help are made on the spot. Meanwhile, frenzied efforts at "headquarters" try to schedule enough stripping machines for the proper time. Seed is ripe for harvesting only a few days. If harvesting is done too soon, immature seed results; if too late, much seed is lost by shattering. Occasions are frequent where paid-for acreage sees not a stripper, because shattering wind, late surge of weeds, or even armyworm invasion ruins the crop.

Of course, in abundant years poor acreage can be ignored in favor of better stands. Nevertheless, there is much guessing and uncertainty, especially in the southern areas. The question there is whether to risk intensive harvest of lean acreage (in expectation that the later northern crop will not be abundant), or go slow fighting for southern grass in expectation of cheaper, abundant northern harvest. Most large operators do both.

Even if the seed in the field were absolutely free, there are many costs—financing, strippers, operations in the field, transportation, cleaning and curing—which set a minimum price for bluegrass.

Equipment

In Kentucky many farmers own their own stripping machines or have continuing traditional arrangements with producers and cleaners. The machines for this less extensive area can be heavier and more expensive than for the West. The Kentucky machine (Fig 2) is designed to "comb" the inflorescence, lifting its teeth through the panicle with a sweeping forward and upward motion that tears loose spikelets and some panicle stems. Seed loss is said to be less with the Kentucky machines than under the flailing action of western machines. This has not always proved so in tests, however.

Seed stripping in the western district utilizes a lighter, cheaper machine than in Kentucky, one that can be quickly disassembled in part and turned end-wise to accommodate about a dozen on a trailer bed (Fig 3). In this fashion they are quickly moved from location to location, relying on locally hired tractors in distant reaches of the bluegrass country for power needs. These strippers may start operations in Missouri in early June and wind up the season in Canada in July. Just as with the Kentucky strippers, the machines are entirely useless for purposes other than bluegrass harvesting. Consequently, used only a few weeks during the year, they cannot merit much capitalization. Western strippers cost $150 to $200 per machine, little more than half that for their counter-part in Kentucky. (Kentucky also has some much more expensive strippers of recent design.)

The western district stripper carries a wooden cylinder oriented horizontally, studded with spikes (nails driven through the wood). This is geared to the wheel and rotates at a rapid speed with forward motion of the stripper. As in Kentucky usually three strippers are pulled in off-set tandem behind a tractor. The spikes kick seed and debris back into a collecting box below and behind the whirling cylinder. Height adjustment on the wheels permits the cylinder to be set to varying grass height.

Processing

Harvesting. Most bluegrass fields are stripped a single time. A scattering of early maturing seedheads is usually ignored, in favor of the later, more abundant crop. Occasionally, a field will be stripped and then have sufficient later inflorescences to merit a second going-over. This

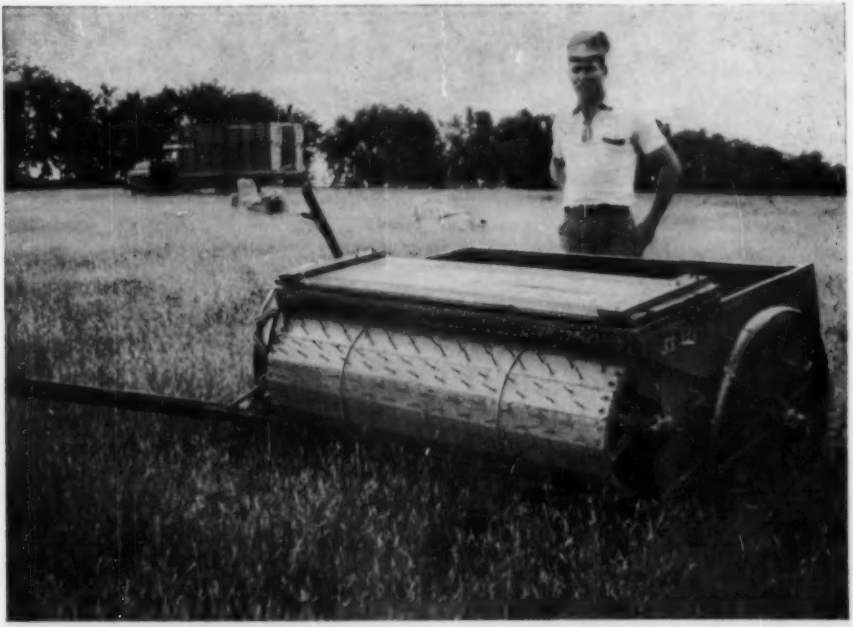

Fig. 3. A close-up of the Western stripper, northwestern Missouri.

is more likely in high price years when acreage is scarce. Chief objective is to keep the strippers operating; each machine must justify its usefulness during the short interval of bluegrass harvest. That is why there will occasionally be stripping of fields which scarcely seem economical. A harvester might lose less in stripping an inadequate field (already paid for) than to have the machine remain idle.

Curing Seed. The green seed cannot be left sacked too long, since fermentation may heat contents enough to destroy germination. In the green state (50% moisture), temperatures much over 100°F. for even a few hours reduce viability. As a result, the freshly sacked seed is almost immediately trucked from the fields to a central curing yard (Fig. 4). Here it is emptied onto the ground in thin layers, repeatedly turned or tedded to facilitate drying and "curing". Rain at this time, except for its inconvenience, will not harm the seed. In fact, records suggest that some rainfall about curing time may coincide with quick germinating crops.

Fig. 4. Colonel Ed Spears and Dr. R. W. Schery examining green seed in Woodford Spears & Sons curing yard near Paris, Kentucky.

Usually three strippers are pulled in tandem behind a tractor. The rough green seed is discharged into a box behind the stripper. At intervals the tractor stops, and the storage boxes are emptied by hand into sacks.

At least, the crops of some dry years have had to have months of "after-ripening" before obviously good seed reached usual germination levels.

The curing yards are in open air, and the seed is generally sun dried. This seems to give better results than indoor curing as has been tried on occasion in empty tobacco barns in Kentucky. All seed that shakes loose from the rough cured seed in the curing yard (just a bluegrass sod clipped close) is swept up by tractor-mounted brushes and is shipped along to the cleaning plant with whatever chaff and dirt accumulate from this final brushing. The cleaning plants are quite efficient in separating chaff and dirt from good seed.

After two or three weeks in the curing yard, rough green seed becomes rough cured seed. A pound of green seed may lose half its weight in curing, or an 8 cent purchase become 16 cents, disregarding all handling costs. It is golden brown when seasoned and is sufficiently dry so that chance of detrimental heating has largely passed.

Cleaning and Packaging. Resacked in the familiar gunny sacks the seed is transported to the cleaning plant. Here it goes through a cleaning operation which, depending upon quality and clean-out percentage, may further reduce its weight by 60%; our 16 cent cured seed now jumps to 40 cents, disregarding all plant and operational costs.

Warehoused seed from the curing yard will be fed gradually into the cleaning mill through the winter. Cleaning begins in most instances with a threshing, a beating operation to break up larger fragments and free the seed. Some years, particularly when seed is clean and from weeded fields of pure bluegrass, so little foreign trash is present that scant threshing is needed.

Following threshing and removal of gross foreign objects, seed passes through a series of blowing and sifting operations that vary somewhat with the cleaning plant, the condition of the seed, the equipment and experience of the cleaner. Blowing lifts away light chaff and dust; shaking over a series of selected mesh screens, agitated in two directions, clears out sticks or materials of a conspicuously different size. If impurities get through these processes, other machines (such as rotating discs or cylinders) can pick out weeds from the bluegrass on the basis of differing surface texture or shape. Many plants employ as a final step an inclined gravity table which sorts the seed by weight. Heavier weight bluegrass seed packs more vigor and is quicker to sprout into a sturdier seedling. Light weight seed which sifts off the upper side of the gravity table must be discounted.

Clean seed, of proved germination and purity, is again sacked for sale to the lawn seed blender. The bluegrass entering the retail package will likely come from many sources, again contributing to genetic mix-up. Seldom is a single producing area good to the exclusion of all others in any given year. Moreover, seed from another year is often blended with the newer crop. In fact, bluegrass generally germinates with greatest assurance a year after harvest. Stored at appropriate temperature and humidity, it can remain viable for years. Seed cleaners are careful to keep their seed thoroughly mixed. If, in handling, light seed should sift to one sack, heavy to another, discrepancies in the tests will make marketing troublesome.

Seed Quality

Certain market standards are set by custom. Although modern seed testing judges weight quickly, by quantity carried at regulated air blast settings, conventional designation of seed is by bushel weight (as "22 pound seed"). In general, bushel weight is indicative of quality, provided seed is viable and reasonably weed-free. Kentucky, in general, produces a lighter

bushel weight seed than the west, and the southern west lighter than the north. This may be a reflection of climatic and soil differences and the length of time soils have been in bluegrass. Twenty-two pound bluegrass is quite satisfactory, and weights above this into the 30 pounds become progressively more attractive.

There are also "purity" specifications. This reflects the amount of hulls, chaff, immature seed, weeds, other crop seeds, stem fragments, etc., that will be permissible, compared to bluegress seeds (enclosed, of course, in their subtending lemma and palea). 85% purity is customarily accepted. This means a guarantee of at least 85% mature bluegrass seeds, 15% allowable for other ingredients, mostly non-viable "inert". State laws limit weed seed content, certain species being classed as "noxious" and inadmissable in appreciable quantities or sometimes not at all. Naturally, the noxious weeds vary from region to region, and accordingly, the list is not uniform among states.

A third criterion for seed is germination. Germination refers to the number of seeds (on a percentage basis) which will sprout in an arbitrarily designated interval under certain standards of temperature, light, and other controlled conditions. For bluegrass 75% germination is usually taken as the minimum. Good lots will germinate appreciably higher. The standard test for bluegrass records percentage of sprout in 28 days, in germinators adjusted for alternating eight hours at 30°C in light, 16 hours at 20°C. in dark. Obviously, humidity should be optimum.

Lawns are a *population* of plants. Perhaps the variability encouraged in bluegrass by the industry's methods as outlined is just what is wanted in a lawngrass. Restriction of genotype that comes with selection, while offering tidy uniformity, may also increase susceptibility to mass disaster, chanced by any large population all alike. Complete failure is unlikely in a lawn from commercial bluegrass seed, nor should undue coddling be necessary, with a grass holding its own through the centuries in all temperate climates.

Utilization Abstract

Spearmint. The kinds and variations of the genus *Mentha* that are of interest to mint growers, both commercial and amateur, have caused a great deal of misunderstanding. One of these, spearmint, classically is *Mentha spicata* L. and as such has been known since Biblical times. A different sort of mint, *Mentha cardiaca* Baker, is an important essential oil crop in the United States. The oil is sold as spearmint oil. *Mentha cardiaca* is recognized in the National Formulary, 10th edition, 1955, where spearmint oil is described as ". . . . the volatile oil distilled with steam from the fresh, over-ground parts of the flowering plant of *Mentha spicata* Linné (*Mentha viridis* Linné) (Common spearmint) or of *Mentha cardiaca* Gerard ex Baker (Scotch spearmint)".

Guenther, in his Essential Oils (3:676-677, 1950), described the two kinds of oil known as spearmint and separated them by common names but apparently did not realize that the plant sources were different species.

Mentha cardiaca is considered by some botanists to be a hybrid of *Mentha arvensis* L. and *Mentha spicata* L. "*Mentha spicata*" of commerce, also used for the distillation of oil, is sterile or but rarely sets seeds. Dr. Ruttle* thinks that this form may represent a hybrid between *M. spicata* L. and *M. rotundifolia* L. or *M. niliaca* Jacq.

* Ruttle, Mable L. *The Herbalist* 4: *24. (1938).*

L.O.W.

Useful Plants in the Canadian Arctic Archipelago. In his "Illustrated Flora of the Canadian Arctic Archipelago", Dr. A. E. Porsild gives brief notes on economic uses of various species. FRUITS. The baked-apple berry (*Rubus chamaemorus*) is the favorite native fruit of the Eskimos, who preserve it in seal oil. Eskimos also collect large quantities of the juicy, sweet fruits of crowberry (*Empetrum nigrum*), even in winter under the snow. Other edible fruits are those of bear berry (*Arctostaphylos alpina* and *A. rubra*), of bilberry (*Vaccinium uliginosum*), and of mountain cranberry (*Vaccinium vitis-idaea* var. *minus*). The berries of the latter remain on the plant all winter and in spring are even more palatable than in autumn. ROOTS AND ROOTSTOCKS. The bistort (*Polygonum viviparum*) produces a pecan-sized, starchy rootstock that is edible raw or cooked. It is a choice delicacy of several Eskimo tribes, who preserve it by freezing or in seal oil. The fleshy roots of licorice-root (*Hedysarum alpinum*), which may be ½ inch thick, are edible and, when cooked, taste somewhat like carrots. Roots of several species of lousewort (*Pedicularis lanata, P. arctica, P. hirsuta,* and *P. sudetica*) may be eaten raw or cooked in soup. GREENS. The flowering stems and/or leaves of several plants are edible raw or cooked: some species of willow (*Salix* spp.), whose young leaves and buds are rich in vitamin C; mountain sorrel (*Oxyria digyna*), whose high vitamin content, wide distribution, and local abundance make it one of the most important edible plants of the arctic; seabeach sandwort (*Arenaria peploides* var. *diffusa*); scurvy grass (*Cochlearia officinalis*); roseroot (*Rhodiola rosea*); willow herb (*Epilobium latifolium*); several species of lousewort (*Pedicularis lanata, P. arctica, P. hirsuta,* and *P. sudetica*); sweet coltsfoot (*Petasites frigidus* and *P. sagittatus*); groundsel (*Senecio congestus*); and dandelions (*Taraxacum* spp.). FLOWERS. Flowers of the willow herb (*Epilobium latifolium*) may be eaten raw as a salad. Eskimo children suck nectar from the flowers of two species of lousewort (*Pedicularis lanata* and *P. arctica*). SOURCES OF FUEL. Some arctic willows (*Salix* spp.), especially the dry, wind-killed stems of *Salix arctica;* ground birch (*Betula glandulosa*); and arctic white heather (*Cassiope tetragona*), whose stems have a high resin content and burn with a hot flame when dry. FOOD FOR MAMMALS AND BIRDS. In winter, twigs and young branches of larger species of willow (*Salix*) are eaten by caribou and muskoxen, and bark and small twigs are eaten by arctic hares and lemmings. Willow buds are one of the main winter foods of ptarmigan. In spring and early summer, young leaves and flowering catkins of willows are eaten by herbivorous animals and birds. Leaves and stems of mountain sorrel (*Oxyria digyna*) are eaten by caribou, muskoxen, and geese. Arctic hares and lemmings prefer the fleshy rhizomes. Bulbils of bistort (*Polygonum viviparum*) are eaten by ptarmigans and lemmings. (A. E. Porsild, *Nat. Mus. Canada Bull.* **146**. *209 pp. 1957).*

(JWT)

Curcuma Root. Curcuma root, used in the east since ancient times as a food seasoning, is derived from a member of the ginger family, *Curcuma longa,* not known in the wild state, and is cultivated in India, Indochina, Malaya, and southern China. Curcuma contains starch, some gum, essential oil, an alkaloid-type compound, as well as wood-fiber and a yellow coloring matter, curcumin. Curcumin is the only vegetable coloring matter that dyes silk and cotton directly a splendid yellow. It is very seldom used any more in Europe for dying because the color fades quickly in the light and, on washing in alkaline soap solutions, assumes a brown shade. Today curcumin is used mainly in the form of alcoholic solutions for the coloring of foodstuffs because, like saffron, it is nontoxic. Butter, cheese, margarine, liqueurs, fruit drinks, cakes, and table jellies are colored with it. The greater part of curcuma root production is used as condiment in countries of its origin. It is the basis of the well-known curry powder. Further additions to curry are ginger, cardamon, kemferia galanga, *Curcuma zedoaria,* coriander, fennel, dill, ajowan, Roman caraway, nutmeg, cinnamon, cloves, vetiver roots, and dried leaves of *Perilla ocymoides.* The composition of the powder varies according to local markets and intended uses. The use of curry is very ancient. It is not only appetizing but also stimulates the kidneys and gall bladder. Curcuma root and related products are used in eastern Asia as medicine for liver troubles. Clinical studies have shown that these root extracts stimulate the flow of gall liquids and so bring about an effective rinsing of the gall bladder. Oil of curcuma could be of some interest for perfumery. *(A. Burger, Perfumery and Essential Oil Record* 49 *(12): 801-802. 1958.)*

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Coffee By-Products. Of the many white, fragrant blossoms of the coffee shrub, only a few produce fruit. Many abscise naturally or are removed from the shrub artificially to strengthen the future crop. These blossoms contain an essential oil with an odor reminiscent of jasmine, cassia, and mimosa that may have possibilities as a new perfume absolute. The fresh pulp of coffee berries, which in most cases is removed before fermentation of the beans, can be converted into a compost for fertilizer. It can also be dried and used as fuel or cattle feed. Coffee hulls are the thin, hard, and brittle pellicle removed from the dried beans by crushing between rollers. They are accumulated in great quantities in coffee plantations, and no use has been found for them. They have been tried as cattle feed but are low in nutritive value and in palatability. Use of them as a fertilizer is futile because they decompose very slowly. They are a burden to coffee growers, who have to spend money to dispose of them. Destructive distillations have been carried out to test coffee hulls as fuel, and the resulting charcoal yields from these tests are comparable to those obtained from hardwoods, although the yield of acetic acid is considerably higher. Another possibility of using coffee hulls is as supporting media in the processing of vinegar. Generally, coke, corn cobs, rattan, or shavings of pine, oak, or beech are used for this purpose. The supporting medium "determines the availability of the bacterial mass, which acts as a catalyst to hasten the oxidation of alcohol to acetic acid and therefore influences the rate at which the conversion takes place." Coffee hulls have been found to have better properties than these other materials, commonly used for this purpose (coke, corn cobs, rattan, and shavings of pine, oak, or beech). *(N. G. M. Nadal, Coffee and Tea Industries* 81 *(8): 9-10, 33-34. 1958.)*

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Ginger in Jamaica. The spice, ginger, consists of sun-dried rhizomes of *Zingiber officinale*. Three principal types of ginger are recognized by the trade: (1) West African ginger, cultivated chiefly in Sierra Leone and, to a much smaller extent, in Nigeria, with a rather dark color, and a pungent, somewhat coarse and camphoraceous flavor; (2) Cochin and Calicut ginger, from the Malabar coast of India, with a faintly lemon-like odor and flavor due to the presence of a small amount of citral; (3) Jamaica ginger, which reaches the market in peeled form. Because of the labor involved in peeling, Jamaican ginger is usually the most expensive. Jamaica ginger, which many experts consider to be the world's finest, is grown in the central part of the island at an altitude from 1,600 to 3,000 feet in hilly country with a loose loam soil of volcanic origin. Years age, plantations of ginger, owned by white planters, sometimes covered hundreds of acres. The mounting difficulty of obtaining labor for this kind of agricultural work has resulted in the disappearance of these large plantings. The growing of ginger is entirely in the hands of over 1,000 native growers who cultivate the spice on plots of one fourth to four acres. Planting takes place from April to July after the spring rains. A ginger field gives the highest yield when planted on new land. A planting lasts several years, but in the fifth year the yield declines to uneconomical levels; so after three years ginger is usually rotated with yams, corn, peas, lentils, etc., to enrich the soil. For proper growth the plant requires plenty of sunshine as well as ample rain in July and August and again in November and December. As the above-ground parts of the plant dry, the root system reaches maturity and is ready for harvest. Roots planted between April and July can be harvested between January and March. The rhizomes are simply dug up with a hoe and then broken by hand into several pieces. The principal root, resulting from last year's growth, is peeled and dried, while the smaller pieces (from 1/3 to 1/4 the total root) are set aside for replanting. Yields of about one ton of dried ginger per acre per year are reported. After digging, the rhizomes are washed and are then peeled, a laborious and time-consuming task. A skilled woman can peel up to 40 lbs. of fresh rhizomes per day. 100 lbs. of fresh rhizomes yield about 80 lbs. of peeled fresh root and 20 lbs. of fresh peels. Peeled root is placed on bamboo mats and exposed to the sun. The full drying process requires from 8 to 12 days. It is important to protect the drying root from rain because moisture will cause mildew, black spots, and general darkening of color. After drying is completed, the producers carry their small lots of ginger to the towns of Christiana or Spaldings, where there are three principal exporters. About 25 to 30% of the ginger harvest is required for replanting, and about 10% is used locally. Jamaica exported about 1,870,000 pounds of ginger in 1957. Ground ginger is used extensively for the flavoring of all sorts of food products. Oleoresin ginger, made by the extraction of ground root with various solvents, serves for the flavoring of soft drinks. Limited quantities of essential oil are prepared by steam distillation and are used as an adjunct in flavors and, to a smaller extent, as a modifier in perfumes and toilet waters. *(E. Guenther, Coffee and Tea Industries* 81 *(12): 73-74. 1958; 82 (1): 169-170. 1959.)*

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BOOK REVIEWS

Annual Review of Plant Physiology. Edited by A. S. Crafts, L. Machlis, and J. G. Torrey. Vol. 9. v + 510 pp. 1958. Annual Reviews, Inc., Palo Alto, Calif. $7.00.

There is little doubt that volume 9 of the Annual Review of Plant Physiology will be as thoroughly read as have been its predecessors in this distinguished series of volumes. The series, modeled after the equally distinguished volumes on biochemistry, physiology, etc. are indispensible for scientists dealing even peripherally with any aspect of plant function or composition.

The subjects selected by the editorial committee for this volume represent a broad cross-section of current research activities. Four papers deal with various facets of the ubiquitous "auxin problem". Two of these discuss the occurrence of auxins and its destruction; the others are concerned with its use in the control of flowering and fruiting and in herbicides. Of the group, the papers on the practical applications are superior to the more theoretical papers which, although containing a plethora of experimental data, are primarily compendia and not reviews of the concepts underlying the research.

Five papers deal with as many aspects of metabolism. There are excellent comprehensive reviews on cytochromes and the biogenesis of flavonoids. The function of ascorbic acid reviewed by L. W. Mapson of Cambridge contrasts sharply with the reviews of auxin physiology in its critical evolution of an immense literature without making the review into a bibliography. The papers on the Quantum yield of photosynthesis and the metabolism of amino acids and proteins are subjects which have been reviewed so frequently that the law of diminishing returns is clearly operative. This is not to be construed as a criticism of the Editors or of the authors—one can only wish for a brief interlude during which new perspectives can be obtained.

The lower plants are represented by a pair of excellent papers, one on the physiology of fresh-water algae, the other being an exciting resume of current and not-so-current work on morphogenesis in lower plants by L. F. Jaffee. This paper should certainly interest morphogenetically-inclined scientists to consider research in this field.

Four reviews on pressing problems in agriculture round out the present volume. They include examinations of salt tolerance, and mineral nutrition of tree crops, as well as papers on the physiology of tobacco by R. A. Steinberg and T. C. Tso, and a discussion of the post harvest physiology of fruits by R. Ulrich.

RICHARD M. KLEIN

Pesticide Handbook. 9th Ed. D. E. H. Frear. College Science Publishers, State College, Penna. 216 pp. Paper bound $1.50; cloth bound $3.00.

This appears to be the only complete compilation of proprietary names of pesticides used in the United States, with data on the composition, manufacturer, and special applications. In addition there is included a classification of products by use or application mode (adjuvants, animal repellents, diluents, fungicides, etc.). Other useful information is included. This represents a very useful manual for anyone handling or using pest control items.

G. M. HOCKING